TRAINING METHODOLOGY: A MULTIDIMENSIONAL APPROACH FOR TEAM SPORTS

EDITED BY: José Afonso, Ana Filipa Silva, Beat Knechtle, Luca Paolo Ardigò, Filipe Manuel Clemente, Rodrigo Ramirez-Campillo, Gibson Moreira Praça, Rodrigo Aquino, Daniel Castillo, Javier Raya-González and Hugo Borges Sarmento

PUBLISHED IN: Frontiers in Psychology and Frontiers in Sports and Active Living

frontiers Research Topics

ISSN 1664-8714
ISBN 978-2-88974-864-8
DOI 10.3389/978-2-88974-864-8

About Frontiers

Frontiers is more than just an open-access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers Journal Series

The Frontiers Journal Series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the Frontiers Journal Series operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to Quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews.
Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area! Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers Editorial Office: frontiersin.org/about/contact

TRAINING METHODOLOGY: A MULTIDIMENSIONAL APPROACH FOR TEAM SPORTS

Topic Editors:
José Afonso, University of Porto, Portugal
Ana Filipa Silva, Research Centre in Sports Sciences, Health Sciences and Human Development (CIDESD), Portugal
Beat Knechtle, University of Zurich, Switzerland
Luca Paolo Ardigò, University of Verona, Italy
Filipe Manuel Clemente, Polytechnic Institute of Viana do Castelo, Portugal
Rodrigo Ramirez-Campillo, Andres Bello University, Chile
Gibson Moreira Praça, Federal University of Minas Gerais, Brazil
Rodrigo Aquino, Federal University of Espirito Santo, Brazil
Daniel Castillo, University of Valladolid, Spain
Javier Raya-González, Universidad Isabel I de Castilla, Spain
Hugo Borges Sarmento, University of Coimbra, Portugal

Citation: Afonso, J., Silva, A. F., Knechtle, B., Ardigò, L. P., Clemente, F. M., Ramirez-Campillo, R., Praça, G. M., Aquino, R., Castillo, D., Raya-González, J., Sarmento, H. B., eds. (2022). Training Methodology: A Multidimensional Approach For Team Sports. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-88974-864-8

Table of Contents

frontiers in Psychology

EDITORIAL
published: 16 March 2022
doi: 10.3389/fpsyg.2022.862465

Editorial: Training Methodology: A Multidimensional Approach for Team Sports

Ana Filipa Silva[1,2,3], *José Afonso*[4], *Hugo Sarmento*[5], *Daniel Castillo*[6], *Gibson Moreira Praça*[7], *Javier Raya-González*[8], *Luca Paolo Ardigò*[9], *Rodrigo Aquino*[10], *Rodrigo Ramirez-Campillo*[11], *Beat Knechtle*[12,13] and *Filipe Manuel Clemente*[1,2,14]*

[1] Escola Superior Desporto e Lazer, Instituto Politécnico de Viana do Castelo, Rua Escola Industrial e Comercial de Nun'Álvares, Viana do Castelo, Portugal, [2] The Research Centre in Sports Sciences, Health Sciences and Human Development (CIDESD), Vila Real, Portugal, [3] Research Center in Sports Performance, Recreation, Innovation and Technology (SPRINT), Melgaço, Portugal, [4] Centre for Research, Education, Innovation and Intervention in Sport, Faculty of Sport of the University of Porto, Porto, Portugal, [5] University of Coimbra, Faculty of Sport Sciences and Physical Education, Research Unit for Sport and Physical Activity, Coimbra, Portugal, [6] Faculty of Education, Universidad de Valladolid, Soria, Spain, [7] Sports Department, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil, [8] Faculty of Health Sciences, University Isabel I, Burgos, Spain, [9] Department of Neurosciences, Biomedicine and Movement Sciences, School of Exercise and Sport Science, University of Verona, Verona, Italy, [10] Department of Sports, Center of Physical Education and Sports, Federal University of Espírito Santo, Vitória, Brazil, [11] Exercise and Rehabilitation Sciences Laboratory, Faculty of Rehabilitation Sciences, School of Physical Therapy, Universidad Andres Bello, Santiago, Chile, [12] Institute of Primary Care, University of Zurich, Zurich, Switzerland, [13] Medbase St. Gallen Am Vadianplatz, Gallen, Switzerland, [14] Instituto de Telecomunicações, Delegação da Covilhã, Lisboa, Portugal

OPEN ACCESS

Edited and reviewed by:
Michael John Stones, Lakehead University, Canada

****Correspondence:***
Filipe Manuel Clemente
filipe.clemente5@gmail.com

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *25 January 2022*
Accepted: *18 February 2022*
Published: *16 March 2022*

Citation:
Silva AF, Afonso J, Sarmento H, Castillo D, Praça GM, Raya-González J, Ardigò LP, Aquino R, Ramirez-Campillo R, Knechtle B and Clemente FM (2022) Editorial: Training Methodology: A Multidimensional Approach for Team Sports. Front. Psychol. 13:862465. doi: 10.3389/fpsyg.2022.862465

Keywords: sports training, training methodology, sports psychology, athletic performance, sports sciences

Editorial on the Research Topic

Training Methodology: A Multidimensional Approach for Team Sports

The theory and methodology of training combine different factors that support the coach's intervention for maximizing the athlete's performance. Among these factors can be included the testing and monitoring, the definition of targets and structure of intervention, the planning, and the intervention itself or in a larger concept a hybrid model factor supporting performance as recovery strategies, psychological interventions, nutrition, or supplementation.

Since performance is multidimensional, it seems interesting to look for this issue from a different perspective, namely considering interaction among factors and providing reports about those interactions. This was the main rationale for supporting the opening of this Frontiers topic.

Overall, we have published 12 articles in our topic. Different approaches were received, as expected. Although the range of topics of research, it was obvious two major areas in which the articles were focused: (i) routes for integrating psychology into the sports training methodology; and (ii) testing and Monitoring into the sports training methodology.

Among those included in the "routes for integrating psychology into the sports training methodology," it was observed articles were more related with a description of psychological factors, while others were more focused on identifying how to use training interventions by using the psychology background.

Regarding the articles related to testing and monitoring, it was obvious a specific concern in quantifying and qualifying the training intensities and the wellbeing of athletes across the season. Additionally, the characterization of specific exercises, tasks, or interventions was also focused on.

Considering the interest of evidence presented in our topic, following the readers can briefly overview the multitude of topics and the main findings reported in the included articles.

ROUTES FOR INTEGRATING PSYCHOLOGY INTO THE SPORTS TRAINING METHODOLOGY

The research on sport personality traits has increased exponentially over the past decade. However, some aspects need to be better understood, and the study of Piepiora analyzed assessed in a detailed way the personality traits affecting men's performance in team sports. Based on a sample of 300 players from team sports, the authors concluded that there exist differences between team sports in four personality traits, namely: neuroticism, extraversion, agreeableness, and conscientiousness. The author concluded that the distribution levels of personality traits depend on the sport discipline. In this sense, champions of team sports seem to be characterized by: (1) a lower level of neuroticism; (2) a higher level of extraversion, and (3) openness to experiences in relation to other sportsmen. Consequently, an important role must be assigned to those mental training techniques that favor emotional balance, team communication, and tactical thinking skills and are manifested in triggering start-up readiness.

The scientific evidence on fear in competitive athletes is minimal. However, the investigation in extreme sport provides an understanding of how individuals experience fear in high-risk sports. The study of Rogers and Paskevich provides valuable information concerning the Canadian national team (Alpine Ski) men's experience and management of fear. Through a qualitative analysis the authors concluded that one's experience and management of fear may be influenced by confidence and contextual factors. The discrepancy between the athletes' approaches to training and racing, making it difficult to master fear management strategies. Based on those conclusions the authors presented a set of practical recommendation that can be applied by both coaches and sport psychologists.

Bergmann et al. performed a systematic review investigating the influence of practice design and coaching behavior on perceptual-motor and perceptual-cognitive skill acquisition in soccer. Nearly half the studies ($n = 18$) focused on instructional approaches such as Differential Learning, Teaching Games for Understanding and so-called Non-linear Pedagogy. The other half of the studies ($n = 17$) investigated task design and coaches' instructions, but did not follow a specific instructional philosophy, model, or approach. Considerable heterogeneity was found among the studies in both categories (e.g., study design, participants, interventions, comparators, and outcomes), and despite data supporting the use of pedagogical approaches that promote autonomy and self-exploration, more so-called "traditional" approaches also generated improvements in technical outcomes, but their effects on tactical parameters were scarcely explored. Furthermore, most studies had small samples, lacked consideration of relevant confounders, and the average Downs and Black score was merely 55.65%. We support the authors' conclusions that research on instructional models would benefit from more high-quality studies, with randomized designs and, preferably, blinded outcome assessors. As the authors stated, coaches should comprehensively analyze the context and the participants before choosing a specific pedagogical approach, as a "one-size-fits-all" approach is unlikely to exist.

One study translated knowledge and insights from the preparation of the Belgian special forces operators into elite team sports training (Pattyn et al.). The demands for very high performances in contexts of uncertainty and under time pressure, the need to balance respect for the team structure and goals with the requirement of making creative, spontaneous, individual decisions, often needing out-of-the-box solutions, and the year-long demand of readiness for performing are features common to special forces and elite team sports training. The bar is set very high for psychological and physical characteristics, and only a small percentage of candidates achieves the required levels of performance. The authors recommend an integrated development of physical and psychological skills and propose that exercise for prevention of injuries and exercise for rehabilitation share many features. Centered on evolving from a dualistic mind-body thinking to an integrate framework of training processes, the authors propose a bold approach to simultaneously develop both the individual and the team.

In the study of Klatt et al. with elite 46 males and 36 females German beach volleyball players, it was asked to fill out the Big Five Inventory, the Personality Adjective Scale, and the Affective Style Questionnaire. The aim was to assess the personality traits and emotion regulation styles of those athletes. In general, the same personality traits and values were shared among players, i.e., they exhibited a similar profile of personality. That profile includes a higher manifestation of warmth, liveliness, emotional stability, and reasoning, along with lower levels of neuroticism in successful athletes. The players used a variety of emotional regulation styles and reported being moderately to highly satisfied with their team. In fact, neuroticism was the most observed profile, rather than extraversion, agreeableness, and conscientiousness, which proved to be little observed. In general, beach volleyball players can be characterized as spontaneous and lively. This study seems to provide more information for coaches, sport psychologists, and academics for practical application and further scientific research.

In a systematic review with meta-analysis, the authors (Macías et al.) aimed to understand if using conventional or non-conventional sport teaching methodologies could influence students' enjoyment/fun. Eleven studies were included in this analysis. Despite the great heterogeneity of the included studies, the interventions that conducted non-conventional teaching methods showed significant improvements, exhibiting a moderate effect size (0.72, and a 95% CI from 0.48 to 0.96). It seems that the methodology used by teachers plays an important role, with the Sport Education Model showing the highest indices of students' enjoyment/fun. On the other hand, the traditional methodology was not able to promote the enjoyment/fun of boys and girls in sports practice. These suggestions could be useful for teachers and sport coaches to implement during sport practice. Nevertheless, more studies are needed in this field as the GRADE analysis recognized a low quality of the evidence.

TESTING AND MONITORING INTO THE SPORTS TRAINING METHODOLOGY

The participation in a soccer match can lead acute and residual fatigue, inducing a decline in physical performance and increase levels of muscle damage (e.g., creatine kinase activities—Ck) over the following hours and days. In addition, soccer matches can affect the running performance indicators (e.g., total distance covered in different speed thresholds), muscle damage and fatigue differently depending of the playing positions. Therefore, Freire et al. determined the impact of soccer matches on Ck activities, recovery responses and the specific Global Positioning System (GPS)-accelerometry-derived performance analysis according to playing positions (i.e., defenders, offensive midfielders, forwards, wingers, strickers). Twenty-four professional soccer teams of the Brazilian League Serie A participated of the study. Blood Ck activities were measured pre-, immediately post-, and 24 h postmatch, and the GPS-accelerometry parameters were assessed during the matches. The main results demonstrated that Ck responses were higher in all post-match time points compared to pre-match. Furthermore, recovery markers were also identified up to 24 h after the matches, especially for midfielders. The study showed higher values of running performance indicators (e.g., total distance, total load, sprint frequencies above 18 $km \cdot h^{-1}$) in international competitions in South America than at the state level in Rio de Janeiro/Brazil. These results provide new insigths into the information of a specific time-course recovery for each playing positions after elite professional soccer matches. Consequently, coaches and practitioners would adopt a position specific recovery program after the soccer match, particularly for midfielders who are exposed to higher muscle damage after the soccer matches.

Considering the ultimate goal at sports performance is achieving the highest performance to compete, another factor for attending real concern is the wellbeing state of athletes. Specifically, the distribution of training within- and between-weeks from the wellbeing state perspective is crucial to understand the preparation process of athletes for competition. As such, we can find the article of Nobari et al., in which the authors carried out a descriptive–longitudinal study across a full-season (i.e., 36 weeks) for a soccer team. Players completed the Hooper questionnaire after each training session, allowing authors to analyze the weekly variations of wellbeing status relative to fatigue, stress, delayed-onset muscle soreness and sleep quality. Also, Nobari et al. considered to describe these wellbeing variables attending to playing positions (i.e., goalkeeper, fullback, center half, center midfielder, winger, and forward) and moments of the season (i.e., pre-, early-, mid-, and end-season). Main results reported higher fluctuations in wellbeing status indicators at the beginning and at the end of the season in comparison to the middle one. Also, the differences found in some wellbeing variables between training days and match-play were significant, so we can remark the importance of recovery up to 48 h after a match. Finally, these results about wellbeing variations across the season could help coach staffs to make decisions preventing higher risk of injuries.

Training methodology in team sports accounts for various factors that possibly impact players' performance. Besides the training loads, which are extensively investigated in the literature, an interesting factor to be taken into account is the surface on which the training is prescribed. Specifically in soccer, besides the higher specificity of the grass regarding the demands of the competition, the prescription of training sessions in the sand surface has been previously suggested. However, there is no consensus in the literature on this topic. For this reason, Cetolin et al. compared the internal responses of soccer players to high-intensity exercises performed on the sand and the grass. The study recruited nine U-23 soccer players for a randomized repeated measures design in which the players performed a high-intensity intermittent exercise (HIIE) session in both surfaces interspersed by 48 h to reduce the fatigue effect. The oxygen consumption (VO_2), blood lactate concentration and rating of perceived exertion were measured to compare the players' responses between the surfaces. The results, in general, indicated that performing HIIE on sand elicits a higher internal workload in terms of cardiorespiratory, metabolic, and perceptual responses compared to the same exercise performed on the grass. This result outlines the potential of sand-based activities to improve the VO2peak and aerobic running performance.

These authors (Torres-Banduc et al.) assessed female volleyball players for jump performance (jump height, contact time, and reactive strength index), concomitant to eccentric and concentric phase surface electromyography (gastrocnemius medialis, biceps femoris, and vastus medialis muscles), during drop jumps from different drop heights (15–90 cm). Jump performance variables were not significantly ($p > 0.05$) different between drop heights. Moreover, the mean electromyography ranged from 27 to 120% of maximal voluntary isometric contraction, although without significant differences between drop heights. Therefore, jumping performance and most neuromuscular markers were not sensitive to drop jump height (intensity), suggesting that lower drop heights may induce similar training stimulus compared to higher drop heights.

Hamstring complex is the muscle group with the highest incidence in soccer. These injuries are considered as multifactorial, being the hamstring flexibility a relevant risk factor. In this sense, Daga et al. analyzed the hamstring flexibility rate among prepubertal Italian soccer players attending to the age and soccer years of practice. Six-hundred and fourteen outfield soccer players (U8 = 124 players; U9 = 130 players; U10 = 151 players; U11 = 89 players; and U12 = 120 players) from a soccer academy in the city of Turin, Italy, were recruited for this study. Authors used the Sit and Reach Test to assess hamstring flexibility and showed significant differences in flexibility among groups. Specifically, significant differences between U8 and U10, U8 and U11, U8 and U12, U9 and U12, U10 and U12, U11 and

U12 were observed. Additionally, a negative association between the age categories and hamstrings flexibility was found, being similar for body mass index. Due to the observed differences in hamstring flexibility across age groups of prepubertal soccer players, it is necessary to implement individualized stretching protocols to reduce the risk of injuries derived from an excess of hamstring tightness.

Nikolaidis et al. focused on the relationship between the force-velocity (F-v) test and the Wingate anaerobic test (WAnT) players on a cycle ergometer in 158 regional-level male soccer. They aimed at finding (experimental group, EXP, $n = 79$) and validating (control, CON, $n = 79$) two prediction equations of absolute (Ppeak [W]) and mass-normalized [rPpeak ($W \cdot kg^{-1}$)] power as a function of F-v test results. Once theoretical maximal force [F_0 (N)], maximal absolute [P_{max} (W)] and mass-normalized [rP_{max} ($W \cdot kg^{-1}$)] power and maximal velocity [v_0 (rpm)] were calculated from F-v test, prediction equations resulted: $P_{peak} = 44.251 + 7.431 \cdot$body mass [kg]$+0.576 \cdot P_{max}$-$19.512 \cdot F_0$ ($R^2 = 0.833$) and $rP_{peak} = 3.148 + 0.218 \cdot rP_{max} + v_0$ ($R^2 = 0.585$). Equations' validations did not show any significant bias between predicted and true values neither for P_{peak} ($p = 0.661$), nor for rP_{peak} ($p = 0.525$). Overall, F-v test can be suggested as a valid alternative to more fatiguing WAnT, especially when the trainer is interested in the team's average power more than in individual values.

AUTHOR CONTRIBUTIONS

All authors made equal work participating in the writing, revision, and approval of the article.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Psychology

ORIGINAL RESEARCH
published: 09 April 2021
doi: 10.3389/fpsyg.2021.671072

Intra- and Inter-week Variations of Well-Being Across a Season: A Cohort Study in Elite Youth Male Soccer Players

Hadi Nobari [1,2,3]*, Maryam Fani [4], Filipe Manuel Clemente [5], Jorge Carlos-Vivas [2], Jorge Pérez-Gómez [2] and Luca Paolo Ardigò [6]

[1] Department of Physical Education and Sports, University of Granada, Granada, Spain, [2] HEME Research Group, Faculty of Sport Sciences, University of Extremadura, Cáceres, Spain, [3] Sepahan Football Club, Isfahan, Iran, [4] Department of Biological Sciences in Sport and Health, Faculty of Sports Sciences and Health, Shahid Beheshti University, Tehran, Iran, [5] Escola Superior Desporto e Lazer, Instituto Politécnico de Viana Do Castelo, Rua Escola Industrial Comercial de Nun'Álvares, Viana Do Castelo, Portugal, [6] Department of Neurosciences, Biomedicine and Movement Sciences, School of Exercise and Sport Science, University of Verona, Verona, Italy

This study describes the weekly variations of well-being ratings relative to fatigue (wFatigue), stress (wStress), delayed-onset muscle soreness (wDOMS), sleep quality (wSleep), and Hooper questionnaire (wHQ) throughout the season. In addition, the well-being variables for the playing position in different moments of the season were discussed. Twenty-one elite young soccer players U17 took part in this study. From the beginning of the pre-season, well-being status was monitored daily by the HQ method throughout 36 weeks, including four periods: (1) pre-season, (2) early-season, (3) mid-season, and (4) end-season. Players trained at least 3 times per week throughout the season. The main outcome was that, in weeks 33 and 28, the highest [wFatigue: 15.85 ± 3.38 arbitrary units (AU); wHQ: 48.86 ± 9.23 AU] and the lowest (wFatigue: 5.38 ± 1.88 AU; wHQ: 20.43 ± 5.49 AU) wFatigue and wHQ occurred, respectively, although the lowest level of wDOMS happened in week 28 (4.86 ± 2.15 AU), while the highest wDOMS was observed in week 5 (14.65 ± 4.16 AU). The highest wSleep (13.00 ± 2.12 AU) and wStress (11.65 ± 2.92 AU) were observed in weeks 8 and 34, respectively, while the lowest wSleep (5.81 ± 2.29 AU) and wStress (3.76 ± 0.94 AU) were marked in week 29 coincidentally. In the HQ between every weekday, except recovery day, and the day of the match (MD), considerable highest HQ was only revealed in 2 days after MD in contrast to overall team comparison. In the present study, we observed that the well-being changes between different phases of the season as well as between weeks and days of the week with the MD are significant. These results provide a great point of view for coaches and practitioners about well-being variations over a season in elite youth soccer level. As a result, coaches will be more aware about non-functional overreaching and taking measures to prevent it.

Keywords: hooper index, playing position, monitoring, professional, performance, recovery

OPEN ACCESS

Edited by:
Donatella Di Corrado,
Kore University of Enna, Italy

Reviewed by:
Ersan Arslan,
Siirt University, Turkey
Elena Pardos Mainer,
Universidad San Jorge, Spain

***Correspondence:**
Hadi Nobari
hadi.nobari1@gmail.com

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

***Received:** 23 February 2021*
***Accepted:** 09 March 2021*
***Published:** 09 April 2021*

Citation:
Nobari H, Fani M, Clemente FM, Carlos-Vivas J, Pérez-Gómez J and Ardigò LP (2021) Intra- and Inter-week Variations of Well-Being Across a Season: A Cohort Study in Elite Youth Male Soccer Players. Front. Psychol. 12:671072. doi: 10.3389/fpsyg.2021.671072

INTRODUCTION

Monitoring internal training load (TL) has been used extensively and well-discussed in sports, particularly in team sports (Clemente et al., 2017; Nobari et al., 2020b). Quantifying training is a common practice conducted in professional sports teams (Clemente et al., 2019a). Knowledge about the exact impacts of the TLs on youth athletes allows for the management and direction of the variation of stimulus, the optimization of the training individualization, a reduction in risk of injury, the early detection of bad overreaching, and the minimization of the possibility of overtraining syndrome (Wrigley et al., 2012; Gabbett et al., 2017). In addition, youth soccer players may experience different physical and physiological pressures related to their age-specific conditions that can cause premature injury or illness, that is why it is important to assess their monitoring training in these ages (Brink et al., 2010). The main purposes of monitoring are to determine the external and internal load imposed on youth athletes through training and to determine the acute and long-term implications of training (Bourdon et al., 2017; Clemente et al., 2019a, 2021). Mostly, TLs can be identified as either internal or external (Arslan et al., 2017). Internal load defines the physiological influence of training (e.g., effects of heart rate, blood lactate concentrations, or rating perceived exertion). External load usually describes the physical effects of training on players (e.g., distances covered at different speed thresholds, accelerations, decelerations, or jumps) (Rebelo et al., 2012; Wrigley et al., 2012). Furthermore, compared to internal physiological measures, such as heart rate and rating of perceived exertion, other measures of physiological status are less known. Recent literature has introduced the use of the Hooper questionnaire (HQ) (Charlot et al., 2016). HQ is a method based on self-analysis questionnaires involving the well-being ratings relative to fatigue, stress level, delayed-onset muscle soreness (DOMS), and sleep quality/disorders (Hooper and Mackinnon, 1995).

Indeed when athletes do not sufficiently respect the balance between training and recovery, non-functional overreaching (NFOR) can occur (Meeusen et al., 2013). The distinction between NFOR and overtraining syndrome will depend on the clinical outcome and exclusion diagnosis and is very difficult (Meeusen et al., 2013), but semantically, overreaching is an accumulation of training and/or no training stress, resulting in short-term decrement in performance capacity, with or without related physiological and psychological signs and symptoms of maladaptation, in which restoration of performance capacity may take from several days to several weeks (Meeusen et al., 2013; Nobari et al., 2021a). On the other hand, if coaches are aware of a series of signs of overtraining, they can recognize it, although it is accurate diagnosis during competition that causes a decline in performance. Some of these symptoms include decreased appetite, weight loss, headache and allergic responses, sleep disturbance, increased resting heart rate, premature injury, and fatigue (Meeusen et al., 2013).

Awareness of well-being is considered a useful sign for identifying NFOR (Noon et al., 2015). Studies in youth soccer players have shown a connection between declining perceptions of well-being and NFOR (Brink et al., 2012; Noon et al., 2015). Moreover, elite coaches try to prepare athletes with the suitable load that prevents acute or NFOR through the different moments of the season (Jones et al., 2017). Therefore, the HQ measured daily training session, not only allowing better detection of individual signs of pre-fatigue when interpreted along with the players' TLs [4] but also eventually adapting the scheduled TLs of the day in light of the players' status (i.e., amateur or professional players). This will eventually allow the staff and fitness coach to exactly schedule and adapt the TLs to reach optimal performance, with fit players, and to observe optimal weekly load distribution to ensure sufficient post-match recovery and prevent pre-match fatigue (Haddad et al., 2013; Nobari et al., 2020b).

Despite the fact that the above-mentioned research has enhanced our understanding of the variation of fatigue in different periods, namely, identifying some decreases in performance variables (Carling et al., 2015) and the association of TLs with quality-of-life variables, we believe that it is still necessary to cross in a single study the variables of TLs, perception of fatigue, stress, muscle soreness, and sleep and analyze such variance in different types of week (Clemente et al., 2017). Moreover, as we have said before, daily monitoring of internal load and wellness status can help coaches to know more about the impact of training on their players and may help them to prevent risk of NFOR and injury. The data analysis should combine the analysis of daily and weekly data for the different players and the team. Each analysis provides different perspectives about the effective stimulus that is perceived by each athlete. These protocols provide helpful information to handle injury prevention programs (Clemente et al., 2019c; Nobari et al., 2020b). Therefore, this study has three aims: (1) to describe the weekly patterns (within-week comparisons) of well-being across the season with the HQ in terms of weekly fatigue, weekly stress, weekly sleep, and weekly DOMS in elite youth soccer players, (2) to analyze the differences of well-being variables between early-, mid-, and end-season periods, and (3) to compare the well-being variables for playing positions in different moments of the season.

METHODS AND MATERIAL

Participants

Twenty-one elite young soccer players participated in this study (mean ± standard deviation; age, 16.1 ± 0.2 years; height, 176.8 ± 5.6 cm; body mass, 67.3 ± 5.7 kg; BMI, 21.5 ± 1.4 kg/m^2; VO_{2max}, 47.6 ± 3.8 ml kg^{-1} min^{-1}). The participants were the main players of the professional team under-17 (U17). To analyze the differences between playing positions, we differentiate between five fullback (FB), four center half (CH), four center midfielder (CM), five winger (WG), and three forward (FW) (Nobari et al., 2021b). The inclusion criteria in this study were as follows: (i) players who participated in at least 90% of training seasons, (ii) players were not allowed to participate in another training plan along with this study, (iii) each player who was not participating in the match during a week was practicing in a separate session, without the ball or small side games, and (iv) goalkeepers were not included in the statistical analyses. The study was conducted in accordance with the Declaration of Helsinki. Prior to starting, the players and their parents signed an informed consent to participate in this study, which was approved by the Ethics Committee of the Sport Sciences Research Institute (IR.SSRC.REC.1399.060).

Experimental Approach to the Problem

This study is a descriptive–longitudinal study that monitored a full-season for a soccer team. Daily monitoring was observed by players for 36 weeks from the beginning of the preparation season. The full season was divided into four periods according to the team competition schedule: (1) pre-season, weeks (W) 1 to W5, (2) early-season, W6 to W13, (3) mid-season, W14 to W31, and (4) end-season, W32 to W36 (**Table 1**). To analyze the differences between the three in-season periods and by playing position in every in-season periods, all well-being variables were considered for analysis. The description of the typical microcycle pattern and its corresponding analyses were conducted considering only the data from those competition weeks with the most repeated training pattern and that included only one match. The players trained at least 3 times per week during the season. The players had been using the scale of HQ for the last 3 years. Daily sleep, stress, fatigue, and DOMS status data were collected to report changes in weekly wellness status (i.e., HQ) (Hooper and Mackinnon, 1995). The Intermittent Fitness Test (IFT) 30-15 was used to report the participants' level of readiness to calculate their maximum oxygen uptake (VO_{2max}).

Anthropometric Measurements

Anthropometric variables such as standing height (Seca model 213, Germany, with an accuracy of ±5 mm) and weight (Seca model 813, the UK with an accuracy of 0.1 per kilogram) were measured by the techniques provided by the International Society for the Advancement of Kinanthropometry (Norton and Olds, 1996; Rahmat Ali Jafari et al., 2016). These measurements were done between 8 and 11 A.M. (Arazi et al., 2015).

Performance Test

The IFT 30-15 was used to calculate the VO_{2max} of the players. The test consists of 30-s shuttle runs interspersed with 15-s passive recovery periods on a 40-m straight runway. The running velocity starts at 8 km/h^{-1} and is increased by 0.5 km/h^{-1} at every 45-s stage thereafter (Buchheit, 2010). Three lines need to be setup for the 30-15 test. Line A should be 20 m away from line B, and line C should be 20 m away from line B and therefore 40 m from line A. For warm-up in these tests, the players performed 10 min of standard warm-up, such as jogging, dynamic stretching, some ABC run drills, and submaximal short speeds under the supervision of fitness coach of the team. After the warm-up, all the players were divided into groups of four. Standing on line A, after hearing a "Ready, go!" signal from the speakers, they started running to line B and C for 30 s. After that, they would take themselves to another line for the next step. If the participants were totally exhausted or if they could not achieve the 2-m lines for three consecutive times, they can stop on their own volition. This stage level was recorded as velocity of IFT (VIFT). This test was performed in the pre-season and then calculated by the relevant formula: VO_{2max} (ml kg^{-1} min^{-1}) = 28.3–(2.15 × 1)–(0.741 × 17 yrs.)–(0.0357 × weight) + (0.0586 × 17 years × VIFT) + (1.03 × VIFT). VIFT was considered as the final speed of the player in the exhaustion test (Buchheit, 2010).

Well-Being Status Monitoring

The HQ is a self-report questionnaire based on a seven-point scale involving the well-being status relative to stress, fatigue, DOMS, and sleep quality (Clemente et al., 2017; Nobari et al., 2020a). The HQ is the summation of four subjective ratings (Hooper and Mackinnon, 1995). HQ was applied 30 min before each session. In this questionnaire, number one means good condition, and number seven means very bad condition. Prior to the research, the players were familiarized with the scale (at least 3 years of using HQ). The following accumulated data were obtained for each variable by the sum of a week: (i) wStress, (ii) wFatigue, (iii) wDOMS, (iv) wSleep, and (v) wHQ. The data collection occurred individually to avoid the players from hearing the scores of other teammates. The daily data register was made in Excel.

Statistical Analysis

Descriptive statistics are presented as mean and standard deviation (SD). Shapiro–Wilk and Levene's tests were executed

TABLE 1 | Monitoring during the full season.

Year	**2019**										**2020**
Months	**May**	**June**	**July**	**Aug**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Dec**	**Jan**
Weeks	1–4	5–8	9–12	13	14–16	17–20	21–24	25–28	29–31	32	33–36
TS	20	23	19	4	15	21	20	18	14	5	20
Phase	**First PP**	**Regional league**								**Second PP**	**Best of Iran (National)**
Periods	**Pre-season**	**Early-season**			**Mid-season**					**End-season**	
OG	–	–	–	–	3	3	4	5	3	–	8
NOG	2	3	3	–	–	–	–	–	–	–	–

TS, training session; PP, preparation phase; OG, official games number; non-official games number; W, week.

for verifying data normality and homogeneity, respectively. Changes between the three in-season periods were assessed using a repeated-measures analysis of variance (ANOVA), followed by Bonferroni *post-hoc* test for pairwise comparisons. Partial eta-square (η_p^2) was calculated as the effect size of the repeated-measures ANOVA. Similar procedures were applied for analyzing the possible differences between every weekday and the match day (MD) in HQ during a common competition microcycle. Additionally, a one-way ANOVA was applied to compare the different well-being variables, by playing position, in each in-season period. Hedges' *g* effect size with 95% confidence interval was also calculated to determine the magnitude of pairwise comparisons for between-period comparison. The Hopkins' thresholds for effect size statistics were used as follows: ≤0.2, trivial; >0.2, small; >0.6, moderate; >1.2, large; >2.0, very large; and >4.0, nearly perfect 4. The significance level was set at $P \leq 0.05$. The Statistical Package for Social Sciences (SPSS, version 25.0; IBM SPSS Inc., Chicago, IL) was used for computations.

RESULTS

Figure 1 shows the weekly patterns for well-being variables (wSleep, wDOMS, wFatigue, wStress, and wHQ) across the full season and its periods. Coincidentally, the highest and the lowest wFatigue [↑: 15.85 ± 3.38 arbitrary units (AU); ↓: 5.38 ± 1.88 AU] and wHQ (↑: 48.86 ± 9.23 AU; ↓:20.43 ± 5.49 AU) occurred in weeks 33 and 28, respectively. The lowest wDOMS also happened in week 28 (4.86 ± 2.15 AU); however, the highest wDOMS was observed in week 5 (14.65 ± 4.16 AU). Besides this, the highest wSleep (13.00 ± 2.12 AU) and wStress (11.65 ± 2.92 AU) were presented in week 8 and week 34, respectively, while the lowest wSleep (5.81 ± 2.29 AU) and wStress (3.76 ± 0.94 AU) were coincidentally observed in week 29.

Figure 2 displays the daily pattern and comparisons between every weekday and the MD in the HQ during a common competition microcycle for the overall team and by playing position. Repeated-measures ANOVA only revealed significant highest HQ in MD^{+2} (2 days after match day) ($P < 0.001$) compared to MD for overall team comparison. No differences were found for the rest of the overall team comparisons and neither for analyses by playing position ($P > 0.05$).

Results of repeated-measures ANOVA revealed differences between season periods in wSleep ($P < 0.001$, $\eta_p^2 = 0.378$), wDOMS ($P < 0.001$, $\eta_p^2 = 0.664$), wFatigue ($P < 0.001$, $\eta_p^2 = 0.743$), wStress ($P < 0.001$, $\eta_p^2 = 0.916$), and wHQ ($P < 0.001$,

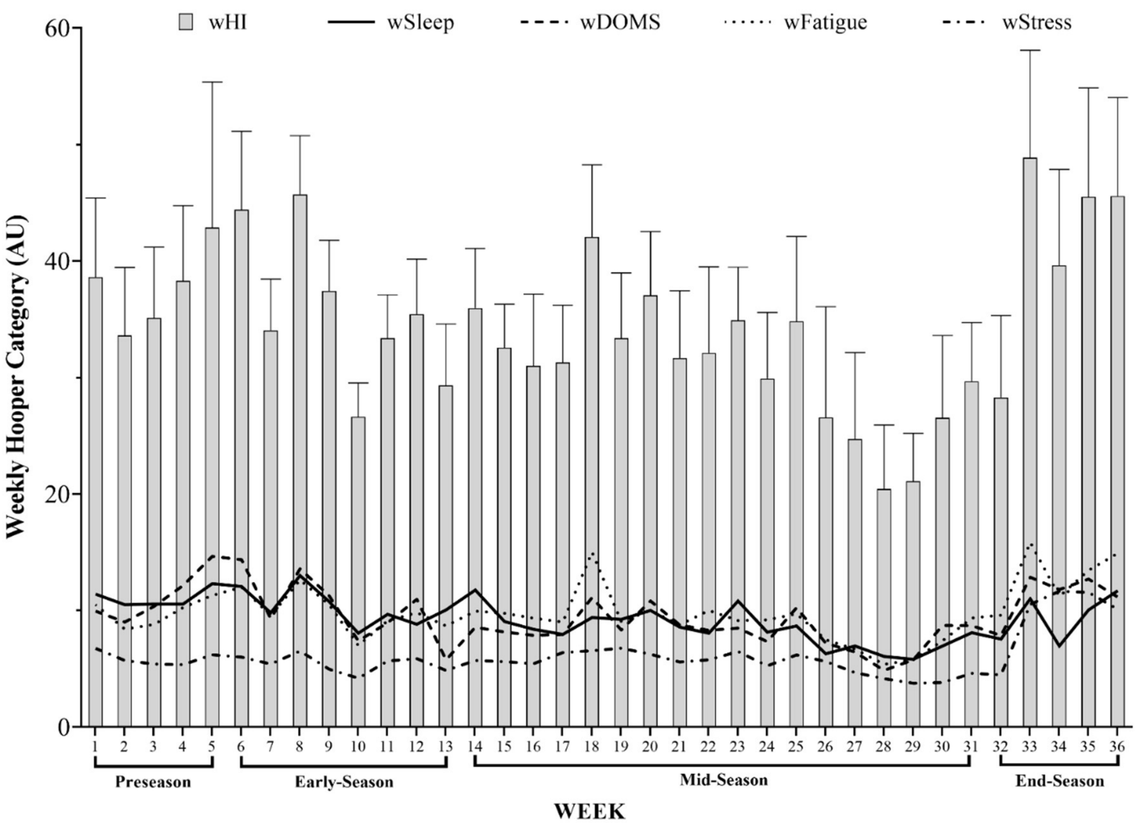


FIGURE 1 | Description of weekly patterns for well-being variables across the season. wSleep, weekly sleep; wDOMS, weekly muscle soreness; wFatigue, weekly fatigue; wStress, weekly stress; wHQ, weekly Hooper questionnaire.

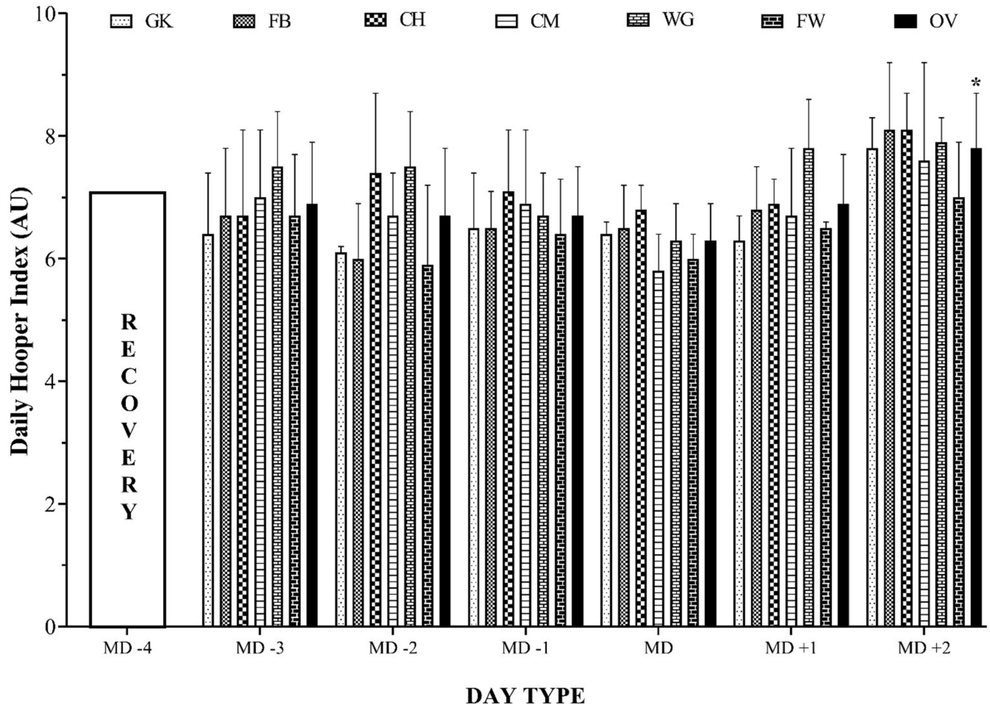


FIGURE 2 | Daily pattern and comparisons between every weekday and the match day in the Hooper questionnaire during a common competition microcycle for the overall team and by playing position. GK, goalkeeper; FB, fullback; CH, center half; CM, center midfielder; WG, winger; FW, forward. *Significant differences for $P \leq 0.05$ compared to MD, match day.

$\eta_p^2 = 0.873$). **Table 2** presents the pairwise comparisons between all in-season periods for wSleep, wDOMS, wFatigue, wStress, and wHQ. Overall, the end-season presented a significantly greater wDOMS, wFatigue, wStress, and wHQ compared to early-season (wDOMS: $P = 0.026$, $g = 0.82$; wFatigue: $P < 0.001$, $g = 1.96$; wStress: $P < 0.001$, $g = 4.76$; wHQ: $P < 0.001$, $g = 2.79$) and mid-season (wDOMS: $P < 0.001$, $g = 2.35$; wFatigue: $P < 0.001$, $g = 2.68$; wStress: $P < 0.001$, $g = 4.67$; wHQ: $P < 0.001$, $g = 3.87$). The early-season had a likewise significantly greater wDOMS ($P < 0.001$, $g = -1.54$), wFatigue ($P = 0.003$, $g = -0.91$), and wHQ ($P < 0.001$, $g = -1.63$) compared to mid-season. However, no differences in wStress ($P = 1.000$, $g = 0.09$) were reported when the early-season and mid-season periods were compared. Besides this, meaningful greater values of wSleep were observed for early-season compared with mid-season ($P = 0.001$, $g = -1.16$) and for mid-season compared with end-season ($P = 0.002$, $g = 0.62$). However, no differences in wSleep were observed when early-season and end-season were compared ($P = 0.551$, $g = -0.35$).

The comparisons between the different playing positions are displayed in **Tables 3–5** for the early-season, mid-season, and end-season, respectively. Overall, the results of one-way ANOVA revealed no significant differences between playing positions for any well-being variable in the different in-season periods ($P > 0.050$). Thus, *post-hoc* tests were not applied for analyzing pairwise comparisons.

DISCUSSION

In this study, daily monitoring was noted by players from the beginning of the preparation season for 36 weeks. The full season was divided into four periods. The three aims of this study were to (i) describe the weekly patterns (within-week comparisons) of well-being across the season, (ii) analyze the differences of well-being variables between early-, mid-, and end-season periods, and (iii) compare well-being variables for playing positions in different moments of the season. However, this is the first study that investigated the variance of wellness during the season in different player positions indicating elite youth soccer players.

The main result was that, in week 33 and week 28, the highest and the lowest wFatigue and wHQ occurred, respectively. Although the low level of wDOMS happened in week 28, the highest wDOMS was observed in week 5. The highest wSleep and wStress were demonstrated in week 8 and week 34, correspondingly, while the lowest wSleep and wStress were coincidentally observed in week 29. The daily pattern and comparisons between every weekday and the MD in the HQ also only revealed significant highest HQ in MD^{+2} compared to MD for overall team comparison.

This study is about well-being variables in weekly patterns and different periods of a season. The result indicated that the highest wStress, wFatigue, and wHQ occurred in end-season, and the lowest of them was observed in mid-season. It can be described that, at the end-season, due to the high sensitivity

TABLE 2 | Comparison between season periods, considering well-being variables.

	Season period	Comparison	%Difference (95% CI)	*P*	Hedges' *g* (95% CI)
wSleep (AU)	EarS: 10.16 (1.60)	EarS *vs*. MidS	−19.2 (−27.1 to −10.4)	**0.001**	−1.16 (−1.73 to −0.38)
	MidS: 8.29 (1.86)	EarS *vs*. EndS	−7.1 (−16.0 to 2.9)	0.551	−0.35 (−0.99 to 0.29)
	EndS: 9.51 (2.00)	MidS *vs*. EndS	15.0 (7.3 to 23.2)	**0.002**	0.62 (−0.03 to 1.27)
wDOMS (AU)	EarS: 10.02 (1.29)	EarS *vs*. MidS	−19.8 (−27.2 to −11.7)	**<0.001**	−1.54 (−2.26 to −0.81)
	MidS: 8.05 (1.22)	EarS *vs*. EndS	11.0 (2.9 to 19.7)	**0.026**	0.82 (0.16 to 1.48)
	EndS: 11.12 (1.34)	MidS *vs*. EndS	38.5 (29.0 to 48.6)	**<0.001**	2.35 (1.52 to 3.17)
wFatigue (AU)	EarS: 9.92 (1.23)	EarS *vs*. MidS	−11.9 (−17.7 to −5.6)	**0.003**	−0.91 (−1.58 to −0.24)
	MidS: 8.76 (1.26)	EarS *vs*. EndS	30.8 (18.6 to 44.2)	**<0.001**	1.96 (1.19 to 2.74)
	EndS: 13.00 (1.79)	MidS *vs*. EndS	48.4 (36.7 to 61.0)	**<0.001**	2.68 (1.81 to 3.56)
wStress (AU)	EarS: 5.44 (0.31)	EarS *vs*. MidS	−0.5 (−2.9 to 4.0)	**1.000**	0.09 (−0.55 to 0.72)
	MidS: 5.47 (0.36)	EarS *vs*. EndS	77.7 (66.2 to 89.9)	**<0.001**	4.76 (3.51 to 6.00)
	EndS: 9.73 (1.21)	MidS *vs*. EndS	76.8 (64.6 to 89.9)	**<0.001**	4.67 (3.44 to 5.90)
wHQ (AU)	EarS: 35.55 (2.44)	EarS *vs*. MidS	−14.3 (−19.1 to −9.2)	**<0.001**	−1.63 (−2.37 to −0.90)
	MidS: 30.58 (3.43)	EarS *vs*. EndS	21.9 (16.6 to 27.5)	**<0.001**	2.79 (1.89 to 3.68)
	EndS: 43.35 (3.01)	MidS *vs*. EndS	42.2 (35.5 to 49.3)	**<0.001**	3.87 (2.80 to 4.95)

AU, arbitrary units; wSleep, weekly sleep in AU; wDOMS, weekly muscle soreness in AU; wFatigue, weekly fatigue in AU; wStress, weekly stress in AU; wHQ, weekly Hooper questionnaire in AU; Ear-S, early-season period; Mid-S, mid-season period; End-S, end-season period; P, p-value at alpha level 0.05; Hedges' g (95% CI), Hedges' g effect size magnitude with 95% confidence interval.
Significant differences ($p \leq 0.05$) are highlighted in bold.

of the final competitions, the pressure and intensity of the competitions and the effort to win the championship could influence the results. Similar attitudes are found in some studies, where RPE and salivary cortisol during were enhanced during the final championship matches compared with during regular competition in elite young volleyball players (Moreira et al., 2013). Cumulative fatigue from TLs during the season in youth rugby players may also affect the ratings for wStress, wHQ, and wFatigue, causing them to rise at the end of the season (Oliver et al., 2015).

In addition, in the mid-season, no significant changes were observed for well-being indicators. In most indicators (wFatigue, wSleep, wHQ, wDOMS, and wStress), it was even lower than at any other time during the season. As stated in a study, the daily perceived ratings of sleep quality and muscle soreness have been found to be statistically significantly correlated with daily training load during the pre-season training period in elite Australian Football League (AFL) players (Buchheit et al., 2013; Moalla et al., 2016). In contrast, the relationship between daily training load and perceived ratings of sleep quality and muscle soreness was obvious and not significant in the other study. This may partly reflect the fact that previous observations in AFL players were made during the pre-season period, when the high volume and intensity of training may lead to greater disturbances in perceived ratings of sleep and soreness. In soccer, the high frequency of competition during the in-season phase confirmed that training is more focused on recovery and maintaining physical fitness, which may lead to lesser changes in perceived ratings of sleep and soreness across a typical training week (Thorpe et al., 2015). As we have seen in the present study, the highest number of muscle soreness was in the early-season, as a result of the high training volume, and fortunately, the muscle soreness continued to decrease due to the players' adaptation to training.

The results that related to sleep and stress in the present study were close to each other (Fernández-Fernández et al., 2015) so that their significant changes are related to the early- and end-season. Based on the findings, it seems that the importance and intensity of competition in the end-season have a significant impact on the quality of sleep and increase player stress (Nédélec et al., 2012, 2015) compared with the effects of different intensities (moderate: 60% and high: 80% heart rate reserve) of 40 min of pre-sleep treadmill running (9:20–10:00 p.m.) on sleep onset with a control condition. Compared with the non-exercise control condition, the sleep-onset latency was significantly longer in the high-intensity exercise condition. In addition, the total sleep time was significantly shorter, while sleep efficiency was significant lower following a high-intensity exercise compared with non-exercise. A significant difference was also observed in the subjective scores of "ease of going to sleep" between high-intensity exercise and non-exercise condition (Nédélec et al., 2015). Therefore, due to the high intensity of the final games of the end-season as well as maintaining the position and trying to be the main player at the early-season, it may have affected the quality of sleep and subsequently the stress of the players. On the other hand, a similar result that we encountered in the current study is that sleep and stress fluctuations in mid-seasons were less than in the early- and end-season, as in a study on elite volleyball players the amount of stress level in mid-season was less, which showed that the professional level of the players caused them to have better control over their mental state (Clemente et al., 2019c).

For the daily pattern and comparisons between every weekday and the MD in the HQ during a common competition

TABLE 3 | Outcomes of ANOVA for well-being variables during early-season, considering playing positions.

	Playing position	*F*	*P*
wSleep (AU)	FB: 9.93 (1.79)	0.184	0.943
	CH: 10.25 (0.74)		
	CM: 9.97 (2.51)		
	WG: 10.45 (1.81)		
	FW: 10.88 (0.88)		
wDOMS (AU)	FB: 10.53 (1.90)	0.569	0.689
	CH: 9.80 (0.57)		
	CM: 9.72 (1.63)		
	WG: 10.73 (1.09)		
	FW: 9.67 (1.00)		
wFatigue (AU)	FB: 10.75 (1.67)	1.808	0.177
	CH: 9.54 (0.62)		
	CM: 10.41 (0.67)		
	WG: 9.20 (1.11)		
	FW: 9.33 (0.44)		
wStress (AU)	FB: 5.28 (0.16)	1.663	0.208
	CH: 5.45 (0.38)		
	CM: 5.28 (0.16)		
	WG: 5.68 (0.34)		
	FW: 5.46 (0.29)		
wHQ (AU)	FB: 36.48 (3.48)	0.215	0.926
	CH: 35.04 (1.20)		
	CM: 35.38 (3.81)		
	WG: 36.05 (2.10)		
	FW: 35.33 (0.47)		

AU, arbitrary units; AU, arbitrary units; wSleep, weekly sleep in AU; wDOMS, weekly muscle soreness in AU; wFatigue, weekly fatigue in AU; wStress, weekly stress in AU; wHQ, weekly Hooper questionnaire in AU; FB, fullback; CH, center half; CM, center midfielder; WG, winger; FW, forward; P, p-value at alpha level 0.05.

TABLE 4 | Outcomes of ANOVA for well-being variables during mid-season, considering playing positions.

	Playing position	*F*	*P*
wSleep (AU)	FB: 7.70 (1.58)	1.173	0.360
	CH: 8.70 (1.65)		
	CM: 7.53 (1.50)		
	WG: 9.62 (1.92)		
	FW: 7.74 (2.20)		
wDOMS (AU)	FB: 7.56 (1.00)	0.901	0.486
	CH: 8.29 (0.97)		
	CM: 8.10 (1.22)		
	WG: 8.99 (1.62)		
	FW: 7.89 (1.19)		
wFatigue (AU)	FB: 8.77 (1.39)	2.569	0.078
	CH: 8.67 (1.28)		
	CM: 10.07 (0.46)		
	WG: 9.28 (1.30)		
	FW: 7.39 (0.63)		
wStress (AU)	FB: 5.31 (0.08)	1.374	0.287
	CH: 5.80 (0.50)		
	CM: 5.40 (0.34)		
	WG: 5.43 (0.29)		
	FW: 5.48 (0.34)		
wHQ (AU)	FB: 29.33 (3.52)	1.199	0.349
	CH: 31.46 (3.56)		
	CM: 31.10 (2.88)		
	WG: 32.93 (2.85)		
	FW: 28.50 (3.66)		

AU, arbitrary units; AU, arbitrary units; wSleep, weekly sleep in AU; wDOMS, weekly muscle soreness in AU; wFatigue, weekly fatigue in AU; wStress, weekly stress in AU; wHQ, weekly Hooper questionnaire in AU; FB, fullback; CH, center half; CM, center midfielder; WG, winger; FW, forward; P, p-value at alpha level 0.05.

macrocycle for the overall team and by playing position, no differences were found for the rest of the overall team comparisons, neither for analyses by playing position, and we only saw a significant highest HQ in MD^{+2} compared to MD for overall team comparison. These findings can be related to post-match DOMS, in fact presenting a DOMS not only in the immediate MD^{+1} but also as long as MD^{+2} after the match caused by the inflammation levels (Clemente et al., 2019b). This result is valuable because it shows that recovery on the day of rest is more important than any other factor in the whole macrocycle, and neglecting it increases cumulative fatigue and ultimately decreases performance and causes injury.

Moreover, we tried to examine the changes in the wellness status of the players between the days of the week and between the weeks during the season due to the fact that weekly data prepare information about the accumulative impact of microcycle. Elite athletes required an accumulative training load that causes them to attain the proper stimulus (Nobari et al., 2020b,c). The accumulative training load of elite athletes in a long season involves the fact that the athletes' functional over-reaching is a noticeable section of their training. The analysis of the weekly data demonstrates better the effect of training on the athletes. However, these results show that coaches should use mainly weekly values (e.g., variation from week to week) as an approach to analyze the effect of training on athletes; it must be considered that once the risk of overreaching is detected in the team, athletes' daily information will be necessary to monitor them and have them abstain from reaching NFOR (Clemente et al., 2019c).

Regarding comparison on well-being variables for playing positions in different moments of the season, in different studies, physiological differences in different positions in different players have been reported (Thelwell et al., 2006), but in the present study, there were no differences in well-being variables. It seems that this could be because these players are young at a certain age and their understanding about the well-being situation is the same. In addition, in the present study, only the competition season was considered. In the match season, the well-being variables are closer to each other because all players are under the same pressure at different moments such as stress, decreased quality of sleep, and so on. Ultimately, possibly examining the well-being variables in the preparation season can provide us with more information.

TABLE 5 | Outcomes of ANOVA for well-being variables during end-season, considering playing positions.

	Playing position	F	P
wSleep (AU)	FB: 9.80 (2.46)	0.240	0.911
	CH: 9.85 (2.18)		
	CM: 9.00 (1.14)		
	WG: 8.44 (4.59)		
	FW: 8.47 (2.01)		
wDOMS (AU)	FB: 11.04 (1.37)	0.586	0.677
	CH: 10.50 (0.82)		
	CM: 11.20 (1.07)		
	WG: 11.90 (2.53)		
	FW: 11.93 (1.29)		
wFatigue (AU)	FB: 13.00 (1.48)	0.758	0.568
	CH: 13.80 (1.99)		
	CM: 13.70 (0.26)		
	WG: 12.15 (2.85)		
	FW: 12.13 (1.14)		
wStress (AU)	FB: 9.52 (1.68)	0.448	0.773
	CH: 9.80 (1.25)		
	CM: 9.75 (1.41)		
	WG: 8.16 (4.06)		
	FW: 10.07 (1.30)		
wHQ (AU)	FB: 43.36 (2.31)	1.197	0.350
	CH: 43.95 (3.34)		
	CM: 43.65 (2.73)		
	WG: 35.56 (13.44)		
	FW: 42.60 (0.92)		

AU, arbitrary units; AU, arbitrary units; wSleep, weekly sleep in AU; wDOMS, weekly muscle soreness in AU; wFatigue, weekly fatigue in AU; wStress, weekly stress in AU; wHQ, weekly Hooper questionnaire in AU; FB, fullback; CH, center half; CM, center midfielder; WG, winger; FW, forward; P, p-value at alpha level 0.05.

This study has limitations that need to be considered. First, we measured only one soccer team in the youth age category. It is better to compare several teams with different age groups. Second, it is better to collect this information on the day of recovery because it will provide more accurate information about the wellness of the players during the week. However, this is the first study to look at changes in the well-being of different players between days and weeks during the season. Therefore, more studies should be done in different teams and different countries to generalize the results.

CONCLUSION

The well-being changes between different phases within the season as well as between weeks and days of the week with the MD are significant. In general, the amount of changes in player welfare indicators at the beginning of the season and at the end of the season is impressive, but these changes were less fluctuating in the middle of the season. Also, the well-being indicators did not differ much between different players, but the remarkable point was that the amount of wDOMS on the MD^{+2} was more than during other days compared to MD, which shows the importance of recovery up to 48 h after a match. The general purpose of designing and examining these hypotheses is to make the coaches more aware of the well-being of the players and to consider the appropriate load during the days, weeks, and finally the months of the season. Because regardless of the well-being conditions, the syndrome NFOR becomes apparent and eventually leads to overtraining, and this is the beginning of serious injuries and failure.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the Sport Sciences Research Institute. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

HN, FC, and JP-G designed the study and drafted the paper. HN and MF performed the experiments. HN, MF, LA, and JC-A participated in the data analysis and drafted the manuscript. HN, LA, JP-G, FC, and MF revised the critical manuscript. All the authors read and approved the final version of the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.671072/full#supplementary-material

REFERENCES

Arazi, H., Mirzaei, B., and Nobari, H. (2015). Anthropometric profile, body composition and somatotyping of national Iranian cross-country runners. *Turk. J. Sport Exerc.* 17, 35–41. doi: 10.15314/tjse.49873

Arslan, E., Alemdaroglu, U., Koklu, Y., Hazir, T., Muniroglu, S., and Karakoc, B. (2017). Effects of passive and active rest on physiological responses and time motion characteristics in different small sided soccer games. *J. Hum. Kinet.* 60, 123–132. doi: 10.1515/hukin-2017-0095

Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., et al. (2017). Monitoring athlete training loads: consensus statement. *Int. J. Sports Physiol. Perform.* 12, S2161–S2170. doi: 10.1123/IJSPP.2017-0208

Brink, M., Visscher, C., Coutts, A., and Lemmink, K. (2012). Changes in perceived stress and recovery in overreached young elite soccer players. *Scand. J. Med. Sci. Sports* 22, 285–292. doi: 10.1111/j.1600-0838.2010.01237.x

Brink, M. S., Visscher, C., Arends, S., Zwerver, J., Post, W. J., and Lemmink, K. A. (2010). Monitoring stress and recovery: new insights for the prevention of injuries and illnesses in elite youth soccer players. *Br. J. Sports Med.* 44, 809–815. doi: 10.1136/bjsm.2009.069476

Buchheit, M. (2010). The 30–15 intermittent fitness test: 10 year review. *Myorobie J.* 1:278.

Buchheit, M., Racinais, S., Bilsborough, J., Bourdon, P., Voss, S., Hocking, J., et al. (2013). Monitoring fitness, fatigue and running performance during a pre-season training camp in elite football players. *J. Sci. Med. Sport* 16, 550–555. doi: 10.1016/j.jsams.2012.12.003

Carling, C., Gregson, W., McCall, A., Moreira, A., Wong, D. P., and Bradley, P. S. (2015). Match running performance during fixture congestion in elite soccer: research issues and future directions. *Sports Med.* 45, 605–613. doi: 10.1007/s40279-015-0313-z

Charlot, K., Zongo, P., Leicht, A. S., Hue, O., and Galy, O. (2016). Intensity, recovery kinetics and well-being indices are not altered during an official FIFA futsal tournament in oceanian players. *J. Sports Sci.* 34, 379–388. doi: 10.1080/02640414.2015.1056822

Clemente, F. M., Clark, C., Castillo, D., Sarmento, H., Nikolaidis, P. T., Rosemann, T., et al. (2019a). Variations of training load, monotony, and strain and dose-response relationships with maximal aerobic speed, maximal oxygen uptake, and isokinetic strength in professional soccer players. *PLoS ONE* 14:e0225522. doi: 10.1371/journal.pone.0225522

Clemente, F. M., Martinho, R., Calvete, F., and Mendes, B. (2019b). Training load and well-being status variations of elite futsal players across a full season: comparisons between normal and congested weeks. *Physiol. Behav.* 201, 123–129. doi: 10.1016/j.physbeh.2019.01.001

Clemente, F. M., Mendes, B., Nikolaidis, P. T., Calvete, F., Carriço, S., and Owen, A. L. (2017). Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer. *Physiol. Behav.* 179, 262–267. doi: 10.1016/j.physbeh.2017.06.021

Clemente, F. M., Mendes, B., Palao, J. M., Silvério, A., Carriço, S., Calvete, F., et al. (2019c). Seasonal player wellness and its longitudinal association with internal training load: study in elite volleyball. *J. Sports Med. Phys. Fitness* 59, 345–351. doi: 10.23736/S0022-4707.18.08312-3

Clemente, F. M., Silva, R., Arslan, E., Aquino, R., Castillo, D., and Mendes, B. (2021). The effects of congested fixture periods on distance-based workload indices: a full-season study in professional soccer players. *Biol. Sport* 38, 37–44. doi: 10.5114/biolsport.2020.97068

Fernández-Fernández, J., Boullosa, D., Sanz-Rivas, D., Abreu, L., Filaire, E., and Mendez-Villanueva, A. (2015). Psychophysiological stress responses during training and competition in young female competitive tennis players. *Int. J. Sports Med.* 36, 22–28. doi: 10.1055/s-0034-1384544

Gabbett, T. J., Nassis, G. P., Oetter, E., Pretorius, J., Johnston, N., Medina, D., et al. (2017). The athlete monitoring cycle: a practical guide to interpreting and applying training monitoring data. *Br. J. Sports Med.* 51, 1451–1452. doi: 10.1136/bjsports-2016-097298

Haddad, M., Chaouachi, A., Wong, D. P., Castagna, C., Hambli, M., Hue, O., et al. (2013). Influence of fatigue, stress, muscle soreness and sleep on perceived exertion during submaximal effort. *Physiol. Behav.* 119, 185–189. doi: 10.1016/j.physbeh.2013.06.016

Hooper, S. L., and Mackinnon, L. T. (1995). Monitoring overtraining in athletes. *Sports Med.* 20, 321–327. doi: 10.2165/00007256-199520050-00003

Jones, C. M., Griffiths, P. C., and Mellalieu, S. D. (2017). Training load and fatigue marker associations with injury and illness: a systematic review of longitudinal studies. *Sports Med.* 47, 943–974. doi: 10.1007/s40279-016-0619-5

Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., et al. (2013). Prevention, diagnosis and treatment of the overtraining syndrome: joint consensus statement of the European college of sport science (ECSS) and the American college of sports medicine (ACSM). *Euro. J. Sport Sci.* 13, 1–24. doi: 10.1080/17461391.2012.730061

Moalla, W., Fessi, M. S., Farhat, F., Nouira, S., Wong, D. P., and Dupont, G. J. R. i. S. M. (2016). Relationship between daily training load and psychometric status of professional soccer players. 24, 387–394. doi: 10.1080/15438627.2016.1239579

Moreira, A., Freitas, C. G., Nakamura, F. Y., Drago, G., Drago, M., and Aoki, M. S. (2013). Effect of match importance on salivary cortisol and immunoglobulin A responses in elite young volleyball players. *J. Strength Condition. Res.* 27, 202–207. doi: 10.1519/JSC.0b013e31825183d9

Nédélec, M., Halson, S., Abaidia, A.-E., Ahmaidi, S., and Dupont, G. (2015). Stress, sleep and recovery in elite soccer: a critical review of the literature. *Sports Med.* 45, 1387–1400. doi: 10.1007/s40279-015-0358-z

Nédélec, M., McCall, A., Carling, C., Legall, F., Berthoin, S., and Dupont, G. (2012). Recovery in soccer. *Sports Med.* 42, 997–1015. doi: 10.2165/11635270-000000000-00000

Nobari, H., Ahmadi, M., Pérez-Gómez, J., Clemente, M., Adsuar, J., Minasian, V., et al. (2020a). The effect of two types of combined training on bio-motor ability adaptations in sedentary females. *J. Sports Med. Phys. Fitness.* doi: 10.23736/S0022-4707.20.11736-5

Nobari, H., Aquino, R., Clemente, F. M., Khalafi, M., Adsuar, J. C., and Pérez-Gómez, J. (2020b). Description of acute and chronic load, training monotony and strain over a season and its relationships with well-being status: a study in elite under-16 soccer players. *Physiol. Behav.* 225:113117. doi: 10.1016/j.physbeh.2020.113117

Nobari, H., Kargarfard, M., Minasian, V., Cholewa, J. M., and Pérez-Gómez, J. (2021a). The effects of 14-week betaine supplementation on endocrine markers, body composition and anthropometrics in professional youth soccer players: a double blind, randomized, placebo-controlled trial. *J. Int. Soc. Sports Nutr.* 18:20. doi: 10.1186/s12970-021-00417-5

Nobari, H., Silva, A. F., Clemente, F. M., Siahkouhian, M., García-Gordillo, M. Á., Adsuar, J. C., et al. (2021b). Analysis of fitness status variations of under-16 soccer players over a season and their relationships with maturational status and training load. *Front. Physiol.* 11:597697. doi: 10.3389/fphys.2020.597697

Nobari, H., Tubagi Polito, L. F., Clemente, F. M., Pérez-Gómez, J., Ahmadi, M., Garcia-Gordillo, M. Á., et al. (2020c). Relationships between training workload parameters with variations in anaerobic power and change of direction status in elite youth soccer players. *Int. J. Environ. Res. Public Health* 17:7934. doi: 10.3390/ijerph17217934

Noon, M. R., James, R. S., Clarke, N. D., Akubat, I., and Thake, C. D. (2015). Perceptions of well-being and physical performance in english elite youth footballers across a season. *J. Sports Sci.* 33, 2106–2115. doi: 10.1080/02640414.2015.1081393

Norton, K., and Olds, T. (1996). *Anthropometrica: A Textbook of Body Measurement for Sports and Health Courses.* Sydney: UNSW press.

Oliver, J. L., Lloyd, R. S., and Whitney, A. (2015). Monitoring of in-season neuromuscular and perceptual fatigue in youth rugby players. *Eur. J. Sport Sci.* 15, 514–522. doi: 10.1080/17461391.2015.1063700

Rahmat Ali Jafari, A. D., Bahman M., and Hadi, N. (2016). Anthropometric and bio-motor abilities profile of young elite wrestlers. *Phys. Educ. Stud.* 20, 63–69. doi: 10.15561/20755279.2016.0608

Rebelo, A., Brito, J., Seabra, A., Oliveira, J., Drust, B., and Krustrup, P. (2012). A new tool to measure training load in soccer training and match play. *Int. J. Sports Med.* 33, 297–304. doi: 10.1055/s-0031-1297952

Thelwell, R. C., Greenlees, I. A., and Weston, N. J. (2006). Using psychological skills training to develop soccer performance. *J. Appl. Sport Psychol.* 18, 254–270. doi: 10.1080/10413200600830323

Thorpe, R. T., Strudwick, A. J., Buchheit, M., Atkinson, G., Drust, B., and Gregson, W. (2015). Monitoring fatigue during the in-season competitive phase in elite soccer players. *Int. J. Sports Physiol. Perform.* 10, 958–964. doi: 10.1123/ijspp.2015-0004

Wrigley, R., Drust, B., Stratton, G., Scott, M., and Gregson, W. (2012). Quantification of the typical weekly in-season training load in elite junior soccer players. *J. Sports Sci.* 30, 1573–1580. doi: 10.1080/02640414.2012.709265

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer EA declared a past co-authorship with one of the authors FC.

frontiers in Psychology

ORIGINAL RESEARCH
published: 21 May 2021
doi: 10.3389/fpsyg.2021.679724

Assessment of Personality Traits Influencing the Performance of Men in Team Sports in Terms of the Big Five

*Paweł Piepiora**

Department of Sports Didactics, Faculty of Physical Education and Sports, University School of Physical Education in Wrocław, Wrocław, Poland

The purpose of this article is to define the perspective from which a coach should analyze and evaluate personality traits that influence sports performance in team sports. The subjects of the research are Polish players (N = 300) in senior age (20–29 years) from 10 team sports (each n = 30). A sample of champions (n = 13) was selected from the study population, and the Big Five model was applied to examine their personality with the use of the NEO Five-Factor Inventory questionnaire. Statistical analyses were performed with the IBM SPSS Statistics software, version 25. The study revealed statistically significant differences between team sports in four personality traits: neuroticism, extraversion, agreeableness, and conscientiousness. Champions of team sports were characterized by a lower level of neuroticism, a higher level of extraversion, and openness to experiences in relation to other sportsmen. It was also confirmed that the personality traits distribution levels depend on the sport discipline. Therefore, an important role must be assigned to those mental training techniques that favor emotional balance, team communication, and tactical thinking skills and are manifested in triggering start-up readiness.

Keywords: sport psychology, personality, team sports, championship, assessment

OPEN ACCESS

Edited by:
Ana Filipa Silva,
Polytechnic Institute of Maia, Portugal

Reviewed by:
Lara Carneiro,
Instituto Universitário da Maia (ISMAI), Portugal
Bogdan Włodzimierz Zawadzki,
University of Warsaw, Poland

***Correspondence:**
Paweł Piepiora
pawel.piepiora@awf.wroc.pl
orcid.org/0000-0002-6525-3936

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *12 March 2021*
Accepted: *29 April 2021*
Published: *21 May 2021*

Citation:
Piepiora P (2021) Assessment of Personality Traits Influencing the Performance of Men in Team Sports in Terms of the Big Five. Front. Psychol. 12:679724. doi: 10.3389/fpsyg.2021.679724

INTRODUCTION

Sports competition is related to an enormous mental burden. Sportsmen must publicly demonstrate their superiority over other sportsmen. It is a media test of their training level. Since the physical skills of sportsmen are often of a similar level, it is assumed that the decisive factor in winning is their personality. Research on personality in sport is extremely popular because it is useful in diagnosing the psychological image of individual sportsmen. Thanks to this, a psychologist can determine the problems that a given sportsperson must deal with. The personality diagnosis allows for the definition of the image of the good, desired, strong, and weak features of a given sportsperson (Piepiora, 2020). Such information is essential for coaches because this way they can guide their charges in an appropriate and most beneficial way. Moreover, the coach's lack of knowledge about the specificity of personality characteristics and structure of representatives of various sports may adversely affect the development of the sports of their charges and manifest itself in artificial and ineffective activities.

Today's sport and the ever-increasing demand placed on athletes make all those factors that can help improve the results essential for success. Classified sport is a people's activity aimed at shaping their personality and mental, physical, and motor excellence, enabling the achievement of sports successes (appropriate for gender, age, and sport discipline). Sports results obtained during the competition and classified by institutions established for this purpose are the measure of excellence. In sport, people always strive to present the maximum of their sporting possibilities; however, the goal of self-improvement is always striving for one's own perfection, and not only for showing superiority over competitors. Therefore, in self-improvement, the balance between the values of mind and body should never be disturbed. This could be achieved through developing an attitude of cognitive inquisitiveness by using self-empowering and creative methods in the preparation process (Naglak, 1999). Overcoming the barriers set for oneself is the main goal of sports competition because there is no greater reward for an athlete than the act of self-realization in sports combat. One will not cope with that task when the essence of sport is limited to winning competitors. Setting such a shallow goal for an athlete means that the content of the athlete's preparation for participation in competition is limited only to training perfection in the use of sports techniques and the development of fitness abilities that should be presented during the fight. Wherever only the result counts, other values, such as character training, kindness toward others, and moral virtue, fall into the background. The principle that says sports success is never solely the result of muscle performance should be treated seriously. Success is born and developed where a wise, talented athlete with an extraordinary personality, and well-educated trainer, work together (Lipiec, 1988). That is why athletes are distinguished from people practicing amateur forms of sport, and from people who do not train, by undertaking extreme physical effort, taking into account a high risk of physical injury, tolerating emotional stress in social exposure, maximizing the level of efficiency, achieving long-term goals, and maintaining motivation for high achievements and the ability to postpone gratification (Hardy, 1999; Lazarus, 2000).

The issue of athletes' personality has been intensively studied since the 1980s in terms of the PEN model and other biological dimensions of personality (Eysenck, 1981, 1985; Guiard, 1981). It was found that the personality of athletes influences their involvement in professional sports. Athletes are less neurotic and more extroverted than nontraining people. They show a low level of anxiety, and they highly rate the psychoticism-superego variable (Eysenck et al., 1982). In addition, there are differences in personality between athletes due to the type of undertaken activity – team sports vs. individual sports (Clingman and Hiliard, 1987; Garland and Barry, 1990) – as well as regarding the sports achievements and the division into classified and unclassified sports (Vealey, 1989). Factors that have been used to explain this profile include assertiveness, thrill seeking, competitiveness, and behavior control (Goldberg and Rosolack, 1994).

Further studies on personality in sport in terms of the five-factor personality model known as the Big Five (McCrae and Costa, 2003) show that physically active people differ in conscientiousness from those who do not train (Mirzaei et al., 2013; Allen and Laborde, 2014). Through physical activity, people are able to direct their life goals and be ambitious in life. It has also been proven that sportsmen who train professionally are distinguished from physically active and nontraining people with a higher level of extraversion and conscientiousness, and a lower index of neuroticism (Allen et al., 2011, 2013; Piepiora and Witkowski, 2018; Piepiora, 2019). Hence, sportsmen are distinguished by the quality and quantity of social interactions as well as the level of activity, energy, and the ability to experience positive emotions. Therefore, sportsmen like to surround themselves with people with a positive attitude. In addition, they are well organized, persistent, and motivated in activities aimed at achieving the intended goal. Sportsmen are also less prone to experience negative emotions and less susceptible to psychological stress. These differences are visible in the level of anxiety, aggressive hostility, tendency to depression, impulsiveness, oversensitivity, or shyness due to involvement in sport. In turn, openness to experience and agreeableness were on a similar level among people representing the area of physical culture. Features, such as trust, straightforwardness, altruism, submissiveness, modesty, tendency to be emotional, imagination, aesthetics, affection, ability to act, idealism, and valence, do not distinguish sportsmen from physically active people.

However, it cannot be unequivocally stated that sports activity can have a beneficial effect in reducing anxiety and depression (Hill et al., 2010). On the other hand, the possible utility of behavior modification in improving athletic performance due to individual and team sports is noted (Nia and Besharat, 2010; Ilyasi and Salehian, 2011). It can be concluded that athletes are characterized by higher emotional stability, extraversion, and responsibility than non-athletes. On the other hand, openness to experience according to the Costa and McCrae (2007) model and the dimension of psychoticism from Eysenck's (1981) model do not seem to be associated with physical activity.

It is also important that higher-class and successful sportsmen are less neurotic and more extroverted, open-minded, agreeable, and conscientious than the rest of the sportsmen without significant results (Kajtna et al., 2004; Kim et al., 2018; Steca et al., 2018). This indicates that the low level of neuroticism and the remaining high levels of personality traits can be beneficial for sportsmen – since they distinguish the champions from the rest of the sportsmen. Such results were confirmed in the group of martial arts (Piepiora and Witkowski, 2020a) and in the group of individual sports (Piepiora, 2019). Therefore, this study aimed to assess personality traits affecting men's performance in team sports.

MATERIALS AND METHODS

Research Group

The research was conducted between October 1, 2015, and September 30, 2019. The subjects of the research are players ($N = 300$) from 10 team sports, selected on purpose non-randomly from the Polish population of men training competitive sports. Such a selection of respondents was dependent on the voluntary willingness of male athletes to participate in the study and their high position in Polish team sports. Moreover, respondents had to be of senior sports age: between the ages of 20 and 29.

They had to have at least the second sports class, sports experience – at least starting from a cadet age (14 years old), professional training – minimum 3 years, a current competition license, their coach's consent to participate in the study, and documented sports achievements at various levels of competition (national, continental, and world). Athletes who refused to participate in the study were excluded from the selection of leading Polish team sports athletes. Therefore, it was possible to collect 10 homogeneous samples (each $n = 30$) from the following sports: American football, basketball, beach volleyball, floorball, football, futsal, handball, indoor volleyball, rugby, and ultimate frisbee. Then, players with international sports achievements were selected from the entire population of surveyed players and qualified to the champions sample ($n = 13$). The criterion for selecting nonrandom, purposeful respondents to the champions sample was dictated by their documented success (first, second, or third place) at international competitions in given sports disciplines. There were 2 beach volleyball players, 2 floorball players, 2 futsal players, and 7 indoor volleyball players. The remaining sportsmen ($n = 287$) are those with only successes on a Polish (national) level. The author did not receive consent from coaches and players for the use of detailed variables in the study, such as age, seniority in sports, and sports achievement, as the detailed data would compromise the anonymity of the study participants. Moreover, it should be noted that the personality of the respondents and their achievements were verified once, during the study time. The studies on the respondents were not repeated within the span of 4 years (the overall length of the research), and the records of achieved successes were not modified in relation to the further careers of the researched athletes.

Methods

A five-factor personality model, known as the Big Five, was used to examine the players' personality. It includes five main features, factors, or dimensions: neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness, which allow for their separate classification, forming NEOAC, OCEAN, or CANOE acronyms. Upon characterizing the Big Five, one should pay attention to several important aspects of character traits in terms of Costa and McCrae (2007) perspective. These features characterize the so-called "normal personality," although their extreme severity may contribute to the development of behavioral disorders and psychosomatic diseases. In this sense, a simple clinical interpretation should not be adopted in relation to the Big Five model. Dimensions are not of the classical type, but are continuous, and – like other psychological properties – have a normal distribution in the population. The extreme poles of traits are associated with the positive and negative trends in behavior, both for the social environment and for a given individual. Therefore, each personality feature has its advantages and disadvantages. The features meet the criteria required to name the basic dimensions of personality. The formal criteria for the characteristics of the five-factor model of personality were formulated by Costa and McCrae during the discussion on the basic dimensions of personality (Eysenck, 1991, 1992; Costa and McCrae, 1992a,b).

For this purpose, the NEO Five-Factor Inventory (NEO-FFI) personality questionnaire was used due to the study time acceptable for the competitive players in voluntary research. For this study, the NEOAC acronym was adopted. The questionnaire consists of 60 self-descriptive statements, the truthfulness of which in relation to themselves was assessed by the respondents on a five-point scale, varying from the statement "definitely not" to the statement "definitely yes." NEO-FFI has sten norms for five age groups (15–19, 20–29, 30–39, 40–49, and 50–80), developed separately for women and men on the basis of large population samples. In addition, it is internally compatible. The obtained results allow for a full description of the respondents' personality in terms of the Big Five and for forecasting their adaptation possibilities to the professional sport environment (Costa and McCrae, 2007).

Statistical analyses were performed using IBM SPSS Statistics, version 25. A series of one-way ANOVAs were performed. Welch's correction was applied in case of breaking the assumption of homogeneity of the variance. In the case of unequal groups, breaking this assumption is the most problematic from the point of view of drawing conclusions; therefore, this correction is necessary. Parameters were estimated using the bootstrapping method with a sampling set at 5,000 and 95% confidence intervals. On the other hand, when the assumption of homogeneity of variance was broken, Games-Howell tests were used in *post-hoc* analyses. And if the assumption of homogeneity of variance was met, Tukey's tests were used. Additionally, due to the multiple comparisons made within each sport category, it was decided to adopt the Bonferroni correction for the significance level. In each sports category, five one-way ANOVAs were performed, and the level of statistical significance for the ANOVAs was calculated as $\alpha = 0.01$.

Procedure

Each tested player agreed to participate in the research after getting acquainted with the information on the objectives and principles of carrying out, expected effects, and possible benefits for the study participants. The respondents also familiarized themselves with the risk associated with undergoing the study, indicating the mode and possibility of withdrawing from participation in the study at each stage. Moreover, the respondents were informed that they had the possibility to ask questions and obtain answers to them. All respondents consented to the use of the results of the NEO-FFI research, but did not consent to the use of data that would compromise their anonymity. Competitors have this stipulated in their contracts. The respondents had 1 h to respond to the statements of the NEO-FFI personality questionnaire. The research was carried out in groups of up to 30 people. After the research work was completed, the participants' data were coded.

All respondents gave their informed consent to participate in the study. All procedures carried out in the human trials were in accordance with the ethical standards of the institution and/or the National Research Commission and the 1964 Helsinki Declaration and its subsequent amendments. The project received a positive opinion (number 20/2019) from the Senate Committee on Ethics of Scientific Research at the University School of Physical Education in Wrocław.

RESULTS

The obtained results showed significant differences between individual disciplines in the following traits: neuroticism, extraversion, agreeableness, and conscientiousness. The strongest effect was again observed for neuroticism – around 18% of the explained variance. In the analysis of differences in conscientiousness, about 14% of the explained variability was observed. On the other hand, in extraversion and conscientiousness, the differences in the effects amounted to approximately 7 and 6% of the explained variance, respectively.

The highest level of neuroticism was noted among Ultimate Frisbee players, and it was statistically significantly different from all other team sports disciplines. In addition, American football players were also characterized by higher neuroticism than rugby and football players. Floorball players also had a higher neuroticism index than rugby and football players.

Post-hoc tests in the extraversion dimension revealed significant differences, with ultimate frisbee players showing a significantly lower intensity of this trait in relation to football, indoor volleyball, and rugby players. Ultimate frisbee players also showed a lower level of conscientiousness than basketball, football, beach volleyball, and rugby players. Additionally, handball players showed significantly lower conscientiousness than basketball players and rugby players. One significant difference in agreeableness was found between volleyball players and basketball players, with the former having a lower agreeableness marker than the latter. The coefficient values of the performed models of one-way ANOVAs are included in **Table 1**, and the whole is shown in **Figure 1**.

The same analyses were then repeated between the champions and other team sports players. Significant differences were observed for neuroticism and extraversion. The difference in openness to experience was not statistically significant after taking into account Bonferroni correction. However, due to the moderately strong effect, it was also described. Again, a very strong effect was seen in the differences in neuroticism, and moderately strong effects were found for extraversion and openness to experience. Team sports champions were distinguished by a lower level of neuroticism, a higher level of extraversion, and openness to experience in relation to other players. The detailed results are presented in **Table 2** and **Figure 2**.

DISCUSSION

Among the studied population of team sports players, significant differences were found between particular sports disciplines, i.e., in neuroticism, extraversion, agreeableness, and conscientiousness. It was found that there are differences in the intensity of individual personality traits between sports disciplines within team sports. This indicates the existence of differences in the personality of players depending on their sports discipline. The obtained data indicate significant effects of sport on the personality shaping of the assessed players and confirm the reports of other authors (Chirivella and Martinez, 1994; Kajtna et al., 2004; Tok, 2013; Kang et al., 2016; McEwan et al., 2019; Piepiora et al., 2020). Sports activity shapes the personality, and the formed personality traits have an impact on taking solutions in the starting situation. It should be related to the specificity of sports competition and the slightly different psychological requirements that sports disciplines impose on competitors. However, these dissonances have not been noted in openness to experience. Taking into account the specificity of acceptable contact in team sports, it

TABLE 1 | Analysis of differences between team sports disciplines for individual personality traits.

Disciplines	Neuroticism		Extraversion		Openness to experience		Agreeableness		Conscientiousness	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
American football (n = 30)	14.97	4.58	31.67	6.74	26.87	5.08	29.63	7.81	32.33	6.14
Futsal (n = 0)	14.07	7.20	31.73	5.78	24.60	6.01	28.10	5.54	33.23	7.57
Basketball (n = 30)	15.03	5.54	32.63	5.75	25.87	5.38	29.87	6.21	35.57	5.82
Football (n = 30)	11.23	3.35	34.27	3.59	25.13	5.64	28.70	4.77	36.67	5.17
Handball (n = 30)	14.17	4.01	31.07	6.45	25.57	6.67	27.83	5.09	29.90	6.58
Indoor volleyball (n = 30)	13.90	4.26	33.30	4.26	27.03	3.30	25.17	3.71	32.77	5.84
Beach volleyball (n = 30)	14.47	6.84	30.63	6.19	26.40	7.06	28.93	4.43	34.27	6.58
Rugby (n = 30)	11.23	3.35	32.83	4.25	24.87	5.83	28.10	5.30	35.77	5.73
Ultimate frisbee (n = 30)	19.63	4.86	28.83	3.43	23.50	4.81	26.87	3.75	28.33	5.97
Floorball (n = 30)	18.40	7.73	30.83	5.81	24.70	3.90	29.80	6.37	33.03	6.68
F	9.90*		2.53*		1.24*		2.17*		5.21	
df	9; 117.74		9; 117.78		9; 117.75		9; 117.87		9; 290	
p	<0.001		0.008		0.078		0.003		<0.001	
η^2	0.18		0.07		0.04		0.06		0.14	

Correction for heterogeneity of variance.

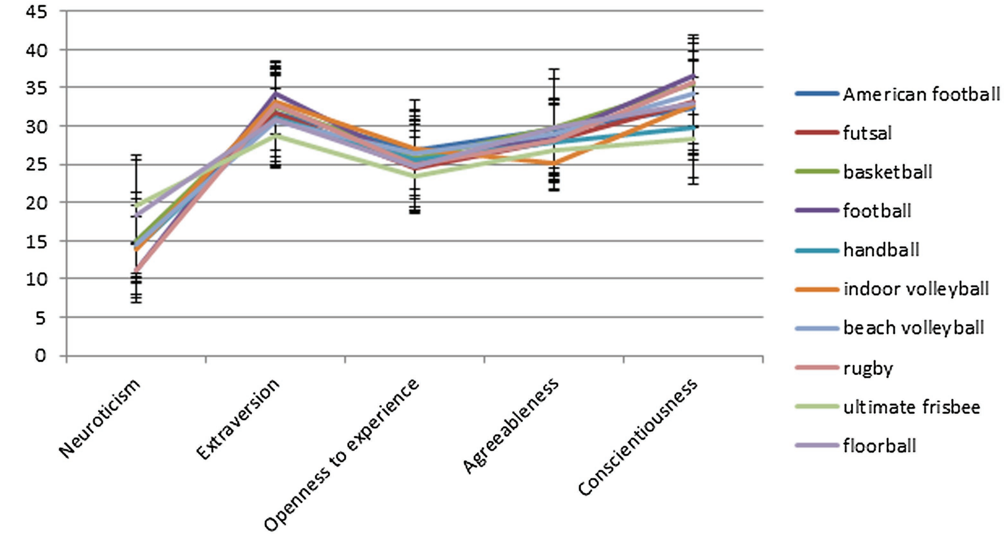


FIGURE 1 | Line chart of personality profiles of team sports players.

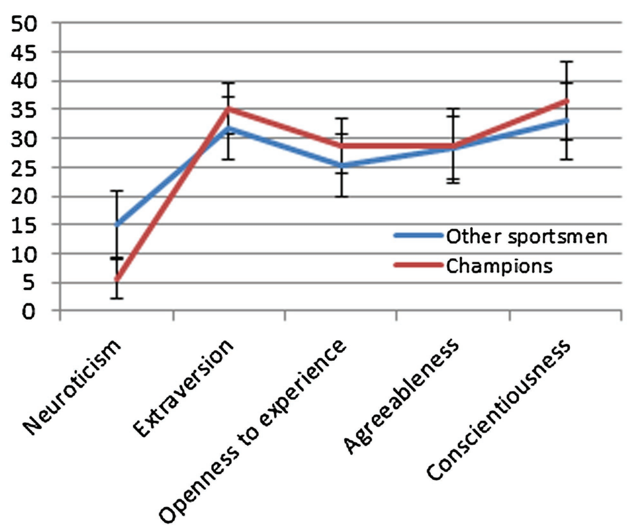


FIGURE 2 | Line chart of personality profiles of champions and other team sportsmen.

was assumed that the lack of differences in openness to experience was revealed primarily in the divergent thinking and creativity of players (Costa and McCrae, 2007). Moreover, the previous experiences of the surveyed players from the earlier periods of their sports careers and the impact of many years of sports training on possible modifications of personality traits should be taken into account. Apart from the influence of the coach and other entities from the players' closest social environment. Therefore, social and cultural factors must also be taken into account.

In the second stage of research, it was discovered that the champions of team sports were distinguished from other players by a lower level of neuroticism and a higher level of extraversion and openness to experience. The obtained empirical evidence confirms the claims of other researchers (Tutko and Ogilvie, 1966; Schur et al., 1977; Garland and Barry, 1990; Lerner and Locke, 1995; Carver and Scheider, 1998; Turk et al., 2001; Gardner and Moore, 2006, 2007). Personality traits can be used as predictors of sports performance. It was presumed that the intensity level of neuroticism, extraversion, and openness to experience in players of team sports may affect the sports performance.

The general profile of sportsmen in terms of the Big Five is low neuroticism, high extraversion, and conscientiousness, as well as average openness to experience and agreeableness (Backmand et al., 2003; McKelvie et al., 2003; Anghel et al., 2009). In the obtained data, it was observed that the team sports champions are characterized by lower neuroticism and higher extraversion and openness to experience. The other factors did not differ statistically from the rest of the players. These results are confirmed by known studies (Piedmont et al., 1999; Shrivastaval et al., 2010; Kim et al., 2018). However, referring to the Polish norms of NEO-FFI interpretation (Costa and McCrae, 2007), all the respondents – champions and other team games players – are distinguished by high rates of extraversion and conscientiousness as well as average rates of openness to experience and agreeableness. The difference between the champions and other athletes is only in the dimension of neuroticism. Champions are characterized by low neuroticism in relation to other team games players, who achieved an average result in this dimension.

Team sports are characterized by conflict resolution methods consisting in demonstrating, in accordance with the adopted rules, superiority over the opponent in a certain range, which leads to gain temporary access to the resources. The will to dominate concerns actions or undertakings that are characterized by a lack of intention to destroy an opponent. The advantage mainly relates to higher performance in the game. That is why champions of team sports are characterized by a low level of

TABLE 2 | Analysis of differences between champions and other team sportsmen in the intensity of individual personality traits.

Variables	Other sportsmen (n = 287)		Champions (n = 13)				
	M	***SD***	***M***	***SD***	***t***	***p***	**Cohen's *d***
Neuroticism	15.12	5.64	5.69	3.35	5.98	<0.001	1.69
Extraversion	31.62	5.47	35.23	4.40	–2.34	0.003	0.66
Openness to experience	25.31	5.50	28.54	4.74	–2.08	0.013	0.59
Agreeableness	28.28	5.50	28.69	6.33	–0.26	0.794	0.07
Conscientiousness	33.03	6.59	36.54	6.70	–1.87	0.058	0.53

neuroticism manifested in the pursuit of direct contact (Piepiora and Witkowski, 2020b), a high level of extraversion manifested in team communication (Ilyasi and Salehian, 2011), and a high level of openness to experiences manifested in thinking divergence and creativity of athletes (Costa and McCrae, 2007), which was not shown by non-champions in team sports.

It should be noted that these findings confirm the role of passion in sport and set new directions for research. A high level of sportsmanship and an autonomous personality orientation lead to a harmonious passion, while a high level of sports valuation and controlled personality orientation favor an obsessive passion (Vallerand et al., 2003, 2008). What makes a champion depends not only on good genetics, innate talent, and physical strength but also on mental abilities and personality traits (Tomar and Singh, 2012; Murnieks et al., 2014).

Accordingly, the forward-looking assessment of personality traits influencing performance in team sports in terms of the Big Five refers to neuroticism, extraversion, and openness to experience. Therefore, in the mental preparation of a sportsperson, particular attention should be paid to those aspects of psychological preparation that are adequate to the components of the above-mentioned dimensions. In team sports games, high emotional stability reflects the confidence and mental resilience of players. High extraversion manifests itself in interpersonal relations between players and communication in the team. And openness to experience reflects the thinking divergence of players, their creativity, and "reading the game," manifested by making tactical decisions.

It should be noted that the obtained research results have great application value at the stage of sport selection, training, and sports competition. They can constitute the basis for the development of appropriate practical directives, important in the sports training of high-class players. It is suggested that in the sports selection of high-class players on the national team, the first verification stage should be the distribution level of personality traits. Candidates meeting the criteria of low neuroticism, high extraversion, and openness to experience may be the desired individuals at the mental selection stage. Only in the second stage, physical criteria should be taken into account, i.e., somatic build and motor, technical and tactical predispositions, and the achievements of the contenders.

Here, the strength and limitations of the test should be equally indicated. The research sample was homogeneous in terms of ethnicity, gender, and age range of 20–29 years. Athletes of other nationalities, women, and other age groups were not included. The research was conducted with a large group of respondents from sports disciplines popular in Poland. However, it was not possible to examine the players from all team sports games trained in Poland. The variables were distributed in equal samples. The groups of champions and other athletes were not even, but they were divided into Polish winners with international sports successes and players at the national level. Therefore, the obtained research results can only be reduced to a specific population of athletes. The author does not question the current results with his research results, but only supplements the existing knowledge about personality in sport.

CONCLUSION

The conducted research proved that the distribution levels of personality traits depend on the sport discipline. And the champions are distinguished from the remaining team sports players (aged between 20 and 29) by a low level of neuroticism and a high level of extraversion and openness to experience. Therefore, an important role must be assigned to those mental training techniques that promote emotional balance, team communication, and tactical thinking skills, and are manifested in triggering start-up readiness.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article, and further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Senate Committee on Ethics of Scientific Research at the University School of Physical Education in Wrocław – number 20/2019. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

REFERENCES

Allen, M. S., Greenlees, I., and Jones, M. (2011). An investigation of the five-factor model of personality and coping behaviour in sport. *J. Sport Sci.* 29, 841–850. doi: 10.1080/02640414.2011.565064

Allen, M. S., Greenlees, I., and Jones, M. (2013). Personality in sport: a comprehensive review. *Int. Rev. Sport Exerc. Psychol.* 6, 184–208. doi: 10.1080/1750984X.2013.769614

Allen, M. S., and Laborde, S. (2014). The role of personality in sport and physical activity. *Curr. Dir. Psychol. Sci.* 23, 460–465. doi: 10.1177/0963721414550705

Anghel, A., Banica, I., and Ionescu, S. (2009). Personality features of elite athletes considering the criterion of the sport practiced. *Sport Sci. Rev.* 1, 5–6.

Backmand, H., Kapiro, J., Kujala, U., and Sarna, S. (2003). Personality and mood of former elite athletes: a descriptive study. *Int. J. Sports Med.* 22, 215–221. doi: 10.1055/s-2001-16382

Carver, C. S., and Scheider, M. F. (1998). *On the Self-Regulation of Behavior*. New York: Cambridge University Press.

Chirivella, E. C., and Martinez, L. M. (1994). The sensation of risk and motivational tendencies in sports: an empirical study. *Personal. Individ. Differ.* 16, 777–786. doi: 10.1016/0191-8869(94)90219-4

Clingman, J. M., and Hiliard, D. V. (1987). Some personality characteristics of the super adherer: following those who go beyond fitness. *J. Sport Behav.* 10, 123–136.

Costa, P. Jr., and McCrae, R. (1992a). Four ways five factors are basic. *Personal. Individ. Differ.* 13, 653–665. doi: 10.1016/0191-8869(92)90236-I

Costa, P. Jr., and McCrae, R. (1992b). Reply to Eysenck. *Personal. Individ. Differ.* 13, 861–865. doi: 10.1016/0191-8869(92)90002-7

Costa, P. Jr., and McCrae, R. (2007). *Personality Inventory NEO-FFI*. Warsaw: Pracownia Testów Psychologicznych.

Eysenck, H. J. (1981). *A Model for Personality*. Berlin-Heidelberg-New York: Springer-Verlag.

Eysenck, H. J. (1985). *The Biological Basis of Personality*. Springfield, IL: Charles C. Thomas.

Eysenck, H. J. (1991). Dimensions of personality: 16, 5 or 3? – criteria for a taxonomic paradigm. *Personal. Individ. Differ.* 12, 773–790. doi: 10.1016/0191-8869(91)90144-Z

Eysenck, H. J. (1992). Four ways five factors are not basic. *Personal. Individ. Differ.* 13, 667–673. doi: 10.1016/0191-8869(92)90237-J

Eysenck, H. J., Nias, D. K., and Cox, D. N. (1982). Sport and personality. *Adv. Behav. Res. Ther.* 4, 1–56. doi: 10.1016/0146-6402(82)90004-2

Gardner, F., and Moore, Z. E. (2006). *Clinical Sport Psychology*. Champaign, IL, USA: Human Kinetics.

Gardner, F., and Moore, Z. E. (2007). *The Psychology of Enhancing Human Performance: The Mindfulness-Acceptance-Commitment (MAC) Approach*. New York: Springer.

Garland, D. J., and Barry, J. R. (1990). Personality and leader behaviours in collegiate football: a multidimensional approach to performance. *J. Res. Pers.* 24, 355–370. doi: 10.1016/0092-6566(90)90026-3

Goldberg, L. R., and Rosolack, T. K. (1994). "The Big Five factor structure as an integrative framework: an empirical comparison with Eysenck's P-E-N model" in *The Developing Structure of Temperament and Personality From Infancy to Adulthood*. eds. C. F. Halverson Jr., G. A. Kohnstamm and R. P. Martin (Hillsdale, NJ: Erlbaum), 7–35.

Guiard, Y. (1981). Sport: Les avantages des gauchers. *Recherche* 12, 894–896,

Hardy, L. (1999). Stress, anxiety and performance. *J. Sci. Med. Sport* 2, 227–233. doi: 10.1016/S1440-2440(99)80175-3

Piedmont, R. L., Hill, D., and Blanco, S. (1999). Predicting athletic performance using the five-factor model of personality. *Personal. Individ. Differ.* 27, 769–777. doi: 10.1016/S0191-8869(98)00280-3

Hill, D. M., Hanton, S., Matthews, N., and Fleming, S. (2010). Choking in sport: a review. *Int. Rev. Sport Exerc. Psychol.* 3, 24–39. doi: 10.1080/17509840903301199

Ilyasi, G., and Salehian, M. H. (2011). Comparison of personality traits between individual and team athletes. *Middle-East J. Sci. Res.* 9, 527–530.

Kajtna, T., Tusak, M., Barić, R., and Burnik, S. (2004). Personality in high-risk sports athletes. *Kinesiology* 36, 24–34.

Kang, C., Bennett, G., and Peachey, J. W. (2016). Five dimensions of brand personality traits in sport. *Sport Manage. Rev.* 19, 441–453. doi: 10.1016/j.smr.2016.01.004

Kim, J., Gardant, D., Bosselut, G., and Eys, M. (2018). Athlete personality characteristics and informal role occupancy in interdependent sports teams. *Psychol. Sport Exerc.* 39, 193–203. doi: 10.1016/j.psychsport.2018.07.011

Lazarus, R. S. (2000). How emotions influence performance in competitive sports. *Sport Psychol.* 14, 229–252. doi: 10.1123/tsp.14.3.229

Lerner, B. S., and Locke, E. A. (1995). The effects of goal-setting, self-efficacy, competition and personality traits on the performance of an endurance task. *J. Sport Exercise Psychol.* 17, 138–152. doi: 10.1123/jsep.17.2.138

Lipiec, J. (1988). *Kalokagatia – szkice z filozofii sportu*. Warszawa–Kraków: PWN.

McCrae, R., and Costa, P. Jr. (2003). *Personality in Adulthood: A Five-Factor Theory Perspective*. New York: Guilford Press.

McEwan, D., Boudreau, P., Curran, T., and Rhodes, R. E. (2019). Personality traits of high-risk sport participants: a meta-analysis. *J. Res. Pers.* 79, 83–93. doi: 10.1016/j.jrp.2019.02.006

McKelvie, S. J., Lemieux, P., and Stout, D. (2003). Extraversion and neuroticism in contact athletes, no contact athletes and non-athletes: a research note. *J. Sport Psychol.* 5, 19–27.

Mirzaei, A., Nikbakhsh, R., and Sharififar, F. (2013). The relationship between personality traits and sport performance. *Eur. J. Exp. Biol.* 3, 439–442.

Murnieks, C. Y., Mosakowski, E., and Cardon, M. S. (2014). Pathways of passion: identity centrality, passion, and behavior among entrepreneurs. *J. Manag.* 40, 1583–1606. doi: 10.1177/0149206311433855

Naglak, Z. (1999). *Metodyka trenowania sportowca*. Wrocław: AWF.

Nia, M. E., and Besharat, M. A. (2010). Comparison of athletes' personality characteristics in individual and team sports. *Procedia. Soc. Behav. Sci.* 5, 808–812. doi: 10.1016/j.sbspro.2010.07.189

Piepiora, P. (2019). "Behaviors of professional athletes in terms of the Big Five model due to the type of contact of the sport discipline" in *Proceedings of the 14th International RAIS Conference on Social Sciences and Humanities at Princeton*; August 19–20, 2019 (Princeton, USA: Research Association for Interdisciplinary Studies (RAIS)), 138–145.

Piepiora, P. (2020). A review of personality research in sport. *Pedagogy Psychol. Sport* 6, 64–83. doi: 10.12775/PPS.2020.06.04.007

Piepiora, P., Maśliński, J., Gumienna, R., and Cynarski, W. J. (2020). Sport technique as a determinant of athletes' personality. *Qual. Sport* 6, 33–43. doi: 10.12775/QS.2020.004

Piepiora, P., and Witkowski, K. (2018). Personality traits of competitive athletes according to the type of pressure exerted on opponents. *S. Afr. J. Res. Sport Phys. Educ. Recreation* 40, 97–109.

Piepiora, P., and Witkowski, K. (2020a). Personality profile of combat sports champions against neo-gladiators. *Arch. Budo* 16, 281–293.

Piepiora, P., and Witkowski, K. (2020b). Self-defence as a utilitarian factor in combat sports, modifying the personality of athletes at a champion level. *Arch. Budo: Sci. Martial Arts Extreme Sports* 16, 63–69.

Schur, K. T., Ashley, M. A., and Joy, K. L. (1977). A multivariate analysis of male athlete characteristics: sport type and success. *Multivar. Exp. Clin. Res.* 3, 53–68.

Shrivastaval, P., Gopal, R., and Singh, Y. (2010). A study of personality dimensions in sports performance. *J. Exercise Sci. Physiother.* 1, 39–42.

Steca, P., Baretta, D., Greco, A., D'Addario, M., and Monzani, D. (2018). Associations between personality, sports participation and athletic success. A comparison of Big Five in sporting and non-sporting adults. *Personal. Individ. Differ.* 121, 176–183. doi: 10.1016/j.paid.2017.09.040

Tok, S. (2013). The Big Five personality traits and risky sport participation. *Soc. Behav. Personal. Int. J.* 39, 1105–1012.

Tomar, R., and Singh, R. (2012). Aggression in athletics: a comparative study. *Ovidius Univ. Ann. Ser. Phys. Educ. Sport Sci. Moment Health* 12, 31–34.

Turk, C. L., Heimberg, R. G., and Hope, D. A. (2001). "Social anxiety disorder" in *Clinical Handbook of Psychological Disorders*. ed. D. H. Barlow (New York: Guilford Press), 114–153.

Tutko, T. A., and Ogilvie, B. C. (1966). *Athletic Motivation Inventory*. San Jose: Institute for the Study of Athletic Motivation.

Vallerand, R. J., Blanchard, C., Mageau, G. A., Koestner, R., Ratelle, C., Leonard, M., et al. (2003). Les passions de 1'Ame: On obesessive and harmonious passion. *J. Pers. Soc. Psychol.* 85, 756–767. doi: 10.1037/0022-3514.85.4.756

Vallerand, R. J., Mageau, G. A., Elliot, A. J., Dumais, A., Demers, M. A., and Rousseaue, F. (2008). Passion and performance attainment in sport. *Psychol. Sport Exerc.* 9, 373–392. doi: 10.1016/j.psychsport.2007.05.003

Vealey, R. (1989). Sport personality: a paradigmatic and methodological analysis. *J. Sport Exercise Psychol.* 11, 216–235. doi: 10.1123/jsep.11.2.216

Conflict of Interest: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 30 July 2021
doi: 10.3389/fpsyg.2021.713106

High-Intensity Intermittent Exercise Performed on the Sand Induces Higher Internal Load Demands in Soccer Players

Tiago Cetolin[1,2], *Anderson Santiago Teixeira*[1,2*], *Juliano Fernandes da Silva*[1], *Alessandro Haupenthal*[3], *Fábio Yuzo Nakamura*[4,5], *Carlo Castagna*[6,7] and *Luiz Guilherme Antonacci Guglielmo*[2]

[1] Research Group for Development of Football and Futsal, Sports Center, Federal University of Santa Catarina, Florianópolis, Brazil, [2] Physical Effort Laboratory, Sports Center, Federal University of Santa Catarina, Florianópolis, Brazil, [3] Department of Health Sciences, Federal University of Santa Catarina, Araranguá, Brazil, [4] Associate Graduate Program in Physical Education University of Pernambuco (UPE)/Federal University of Paraiba (UFPB), João Pessoa, Brazil, [5] Research Centre in Sports Sciences, Health Sciences and Human Development (CIDESD), University Institute of Maia, ISMAI, Maia, Portugal, [6] Fitness Training and Biomechanics Laboratory, Italian Football Federation (FIGC), Technical Department, Florence, Italy, [7] Clinical Sciences and Translational Medicine Department, Faculty of Medicine, University of Rome Tor Vergata, Rome, Italy

OPEN ACCESS

Edited by:
*Rodrigo Aquino,
Federal University of Espirito Santo, Brazil*

Reviewed by:
*Enrico Puggina,
University of São Paulo, Brazil
Carlos Augusto Kalva-Filho,
University of São Paulo, Brazil*

***Correspondence:**
*Anderson Santiago Teixeira
anderson.santiago.teixeira@ufsc.br*

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *21 May 2021*
Accepted: *23 June 2021*
Published: *30 July 2021*

Citation:
Cetolin T, Teixeira AS, da Silva JF, Haupenthal A, Nakamura FY, Castagna C and Guglielmo LGA (2021) High-Intensity Intermittent Exercise Performed on the Sand Induces Higher Internal Load Demands in Soccer Players. Front. Psychol. 12:713106. doi: 10.3389/fpsyg.2021.713106

This study aimed to examine the acute physiological effect of shuttle-run-based high-intensity intermittent exercise (HIIE) performed at the same relative speed (i. e., 100% PS_{T-CAR}) on sand (SAND) and grass (GRASS) in male junior soccer players. Seven Under-23 Brazilian national league ("Série A") soccer players completed four testing sessions in either SAND or GRASS surface condition. The first two testing sessions consisted of performing a maximal progressive shuttle-run field protocol until volitional exhaustion (Carminatti's test, T-CAR), whereas the third and fourth sessions comprised a HIIE session on each ground surface. The HIIE session consisted of three 5-min bouts [12 s shuttle-run (with a direction change every 6 s)/12 s of passive rest] performed at 100% of T-CAR peak speed (PS_{T-CAR}) with 3 min of passive recovery between sets. Measurements of oxygen uptake (VO_2), heart rate (HR), blood lactate concentration ([La]), and rating of perceived exertion (RPE) were performed during all conditions. The SAND condition elicited significantly higher %VO_2peak (94.58 ± 2.73 vs. 87.45 ± 3.31%, $p < 0.001$, $d = 2.35$), %HRpeak (93.89 ± 2.63 vs. 90.31 ± 2.87%, $p < 0.001$, $d = 1.30$), RPE (8.00 ± 0.91 vs. 4.95 ± 1.23 a.u., $p < 0.001$, $d = 2.82$), and [La] (10.76 ± 2.37 vs. 5.48 ± 1.13 mmol/L, $p < 0.010$, $d = 2.84$). This study showed that higher internal workloads are experienced by the players during a single HIIE session performed on a softer surface as SAND, even when the exercise intensity was individualized based on 100%PS_{T-CAR}.

Keywords: intermittent exercise, lactate response, maximal aerobic speed, maximal oxygen uptake (VO) 2 max, training surface

INTRODUCTION

Shuttle-run-based high-intensity intermittent exercises (HIIE) with short intervals is considered as one of the most common forms of interval training in soccer (Dupont et al., 2004; Buchheit and Laursen, 2013a; Da Silva et al., 2015). Shuttle-run-based HIIE with short intervals consists of performing repeated running bouts lasting <45–60 s at an exercise intensity ranging from 100 to 120% of maximal aerobic speed interspersed with periods of rest or lower-intensity active recovery (Buchheit and Laursen, 2013a). Short-interval HIIEs are proposed with the aim to improve a range of soccer performance-related physical fitness attributes, such as aerobic fitness, intermittent running capacity, and repeated sprint ability (Dupont et al., 2004; Buchheit et al., 2008; Da Silva et al., 2015). In addition to the several exercise variables (i.e., work-to-rest ratio, recovery and work intensity, and training volume) (Buchheit and Laursen, 2013a), ground surface is also found to affect HIIE training outcome (Binnie et al., 2014a). Indeed, sand surface was proposed as an alternative training tool to improve relevant fitness components in team sports (Binnie et al., 2013a,b, 2014b). Despite low terrain specificity compared with natural grass and artificial turf, sand training was proposed with the aim to promote high internal load with drills supposedly reporting lower external loads (Binnie et al., 2013a,b, 2014b). Although sand training has gained popularity, studies examining the acute responses of shuttle-run-based HIIE models on cardiorespiratory, metabolic, and perceptual measures in soccer players on this softer surface are lacking, leaving the application of sand surface HIIE sessions speculative in this sport domain.

The effectiveness of different sand training methods not involving shuttle-run-based HIIE models (sport-specific drills, agility, and plyometrics) has been previously reported (Impellizzeri et al., 2008; Binnie et al., 2014a; Ramirez-Campillo et al., 2020). For instance, Binnie et al. (2014a) showed that sand training-induced larger gains in peak oxygen consumption (VO_2peak) than grass training in team-sport players. Ramirez-Campillo et al. (2020) showed that a multi-surface (including sand) plyometric training led to greater improvements in neuromuscular performance compared with grass surface training in soccer players. A recent systematic review with meta-analysis also showed that sand training programs are able to induce positive changes in neuromuscular performance in team-sport players and that both training surfaces (sand and grass) are equally effective to improve sprint and jump performances (Pereira et al., 2021). Nevertheless, it should be noted that training exclusively on the sand was revealed to be detrimental to stretch-shortening cycle development, but tended to improve squat jump height more than grass surface (Impellizzeri et al., 2008). In view of the current evidence, coaches and practitioners can consider sand surface training as a suitable and effective means to enhance aerobic function and power-speed-related capacities in soccer and other team-sport athletes.

There are distinct psychophysiological and biomechanical requirements when running on sand and grass surfaces (Zamparo et al., 1992; Pinnington and Dawson, 2001a,b; Pinnington et al., 2005; Gaudino et al., 2013). Sand-based exercises elicit a higher oxygen uptake (VO_2), heart rate (HR), rating perceived exertion (RPE), blood lactate concentration [La], and muscle activation pattern than grass surface exercises at similar speeds (Zamparo et al., 1992; Pinnington and Dawson, 2001a,b; Pinnington et al., 2005; Gaudino et al., 2013). Sand training also reported to induce lower exercise-induced muscle damage, soreness, and associated negative side effects (e.g., reduced performance), thereby demonstrating a decreased neuromuscular strain (Miyama and Nosaka, 2004). In addition, some changes in kinematic parameters (e.g., decrements in sprint speed and stride length) when running on sand (Pinnington et al., 2005; Alcaraz et al., 2011; Gaudino et al., 2013) has been similar to those observed when performing resisted sprints on grass surface using loads inferior to 20% of the body mass of the athletes (Pereira et al., 2021). Therefore, the compliant nature and unstable characteristics of sand could serve as a practical way to increase overload during workouts, without the need for using additional resistance or supplementary equipment (e.g., elastic bands) (Pereira et al., 2021). This information has relevance for training load prescription optimization across the soccer competitive season. From a practical perspective, replacing some grass training activities for sand-based exercises may be more indicated during the preseason phase (e.g., strength-oriented phase) (Binnie et al., 2014b; Pereira et al., 2021).

To date, the majority of the available studies reporting a greater SAND vs. GRASS internal training load considered only acute physiological responses during drills performed at similar running speeds (Zamparo et al., 1992; Lejeune et al., 1998; Pinnington and Dawson, 2001a,b). Furthermore, these studies used submaximal intensities ranging from 3 to 11 km/h, with the exception of three studies that involved sprint- and sport-specific drill (repeated sprint, agility, power exercises) sessions performed at a maximum perceived intensity (Binnie et al., 2013a,b; Gaudino et al., 2013). According to Binnie et al. (2014b), there is little evidence reporting the energy cost (EC) of running on sand at running speeds > 11 km/h. Similarly, studies comparing VO_2 response during HIIE models performed at the same relative exercise intensity [e.g., running at 100% of maximal aerobic speed (MAS)] on sand and grass training surfaces are also unknown. The time spent at or near VO_2peak—that is, ≥90% of VO_2peak—has been considered a key criterion to define the effectiveness of training stimulus to improve VO_2peak and aerobic running performance in soccer (Buchheit and Laursen, 2013a).

The final speed reached during maximal progressive field tests has been proposed as a valid metric to guide training prescription during shuttle-run-based HIIE sessions (Buchheit, 2008; Buchheit and Laursen, 2013a; Da Silva et al., 2015). More recently, the peak speed derived from Carminatti's test (PS_{T-CAR}) provided a valid estimate of MAS in soccer players and proved to be an accurate reference speed for individualizing running distance (i.e., training intensity) during HIIE models implemented on grass surfaces (Da Silva et al., 2015). However, the acute physiological responses during a HIIE model performed at 100% PS_{T-CAR} on sand surfaces have not received attention to date. Considering that sand-based training has been used as a complementary strategy to promote variability in the training stimulus in team-sport players (Ramirez-Campillo et al., 2020; Pereira et al., 2021), it is of practical relevance to gather evidence regarding the accuracy of the PS_{T-CAR} for HIIE programming on this specific type of surface.

Thus, the present study examined the acute physiological effect of a single shuttle-run-based HIIE session performed at the same relative speed (i.e., 100% PS_{T-CAR}) on sand and grass in male junior soccer players. As a hypothesis of this work, we assumed similar physiological responses across sand and grass HIIE sessions due to the individualization of training intensity across conditions.

MATERIALS AND METHODS

Experimental Approach to the Problem

A randomized repeated-measures design was implemented. All participants were required to complete four testing sessions on two ground surfaces (SAND and GRASS) of distinct compliance/compactness to compare the acute physiological responses between the conditions tested. The testing sessions were carried out at the same time of the day and separated by at least 48 h to minimize any residual fatigue. The first two testing sessions consisted of performing a maximal progressive shuttle-run field test protocol until volitional exhaustion (T-CAR) on each ground surface to determine the relative peak values for the following variables: (i) speed achieved at the end of the T-CAR (PS_{T-CAR}), (ii) heart rate (HR), (iii) blood lactate concentration ([La]), and (iv) RPE. Measurement of peak oxygen uptake (VO_2peak) during the T-CAR protocol was obtained only on the grass surface. The third and fourth sessions comprised a HIIE model performed at 100% PS_{T-CAR} consisting of three sets of 5-min bout [12 s shuttle-run (with a direction change every 6 s)/12 s of passive rest] interspersed with 3 min of passive recovery between sets. Cardiorespiratory (given by VO_2 and HR), metabolic (given by [La]), and perceptual (given by RPE score) responses were measured during the HIIE performed on each ground surface. The air temperature and relative humidity were as follows: T-CAR protocol on GRASS (26.0 ± 3.2°C and 62.1 ± 9.9%) and SAND (25.7 ± 4.4°C and 62.5 ± 9.3%); HIIE model on GRASS (26.6 ± 2.7°C and 53.8 ± 9.7%) and SAND (28.5 ± 2.3°C and 58.6 ± 7.3%).

Participants

The sample size was previously estimated to induce a meaningful detectable effect size (Cohen's *d*) of 0.60 between training surfaces with the assumption of a statistical power of 0.90 at an alpha level of 0.05. The effect size used to generate the sample size was derived from previous investigations comparing the physiological responses between training surfaces assuming HR and RPE measures as references (Pinnington and Dawson, 2001b; Binnie et al., 2013a). The calculations were made using a customized computer software (GPOWER Version 3.1.9.2, Department of Psychology, Bonn University, Bonn, Germany). The analysis suggested a minimum sample of six players. Thus, nine male junior soccer players recruited from Under-23 team of a professional club competing in the Brazilian national league ("Série A") took part in this study. Two players did not complete all testing sessions required for this study. Thus, data from only seven players (age: 18.37 ± 2.32 years; body mass: 65.95 ± 5.51 kg; height: 174.27 ± 6.84 cm; body fat: 10.65 ± 1.65%) were considered. At the time of the investigation (summer season), all the players were in their preseason training cycle. The current research proposal obtained ethical approval from the Local Research Ethics Committee of the University (n° 459.431). The club manager and parents or legal guardians of the participants were informed about the nature of the study including objectives, protocols, and related risks, and the participants provided informed written consent (>18 years) before the commencement of this study. Participation was voluntary and players provided assent (in the case of age < 18 years) after being informed that they could withdraw from the study at any time.

Ground Surface Stiffness Determination

The GRASS testing session was conducted on a natural grass pitch (105 m of length and 68 m of width) at the club facilities, whereas the SAND testing session was performed in a training area with 30 m of length and 17 m of width. Surface stiffness for SAND and GRASS conditions was determined prior to each testing session using a Dynamic Cone Penetrometer (DCP) built by the civil engineering department of this University, weighing 8 kg and dropped from a height of 575 mm. On each occasion, 10 samples (spread over the entire training area) were taken to determine the ground stiffness [i.e., the depth of DCP penetration into the ground (mm)]. The ground stiffness was calculated as the mean value of the 10 samples obtained for each training surface. This technique has been detailed elsewhere (Davies and Mackinnon, 2006).

Cardiorespiratory Measurements

During all the testing sessions, with the exception of the T-CAR protocol on the sand training surface, respiratory gas exchange was measured breath-by-breath using a portable system (Cosmed $K4b^2$, Rome, Italy) to determine VO_2 values. Before each testing session, the following $K4b^2$ calibrations were performed: turbine flowmeter calibration (performed with a 3-L syringe, Quinton Instruments, Seattle, WA, United States), O_2 and CO_2 analysis systems (with a gas mix of 16% O_2 and 5% CO_2 concentrations), delay time, and ambient air calibration. The HR was recorded continuously during all testing sessions using a chest belt *via* short-range radio telemetry (Polar Team Sport System, Polar Electro Oy, Kempele, Finland).

The VO_2 and HR data were reduced to 15 s mean values. The highest values obtained in this 15 s interval for VO_2 and HR during the T-CAR protocol performed on the grass training surface were considered as VO_2peak and HRpeak, respectively (Da Silva et al., 2015; Floriano et al., 2016). During the HIIE model on each training surface, the VO_2 and HR data were reduced to 5 s mean values, and the VO_2 and HR values obtained in each running set was considered as the average of the last two min of exercise (Floriano et al., 2016). The VO_2 and HR responses for each running set (set 1, set 2, and set 3) were expressed as relative percentages of the VO_2peak and HRpeak (%VO_2peak and %HRpeak, respectively) reached in T-CAR.

Blood Lactate Concentration

Capillary blood samples (25 μL) were collected by micropuncture at the ear lobe and then stored into microcentrifuge tubes containing 50 μL NaF (1%) in order to measure [La]. The analysis of blood lactate was performed using an electrochemical analyzer (YSI 2700 STAT, Yellow Springs, OH, United States). The [La] was collected 1 min after the cessation of each test (T-CAR protocol and each running set in both training surfaces).

Rating of Perceived Exertion

The RPE of each player was assessed using the CR-10 scale proposed by Foster et al. (2001). All players were familiarized with the procedure before the study commencement. Players reported their RPE score immediately after the completion of the T-CAR and at the end of each HIIE set performed on both training surfaces.

Carminatti's Test

The test consisted of intermittent shuttle-runs of 12 s performed between 2 lines set at progressive distances with a 6-s recovery time between each run and a total stage time of 90 s. The protocol had a starting velocity of 9 km/h over a running distance of 30 m (15 m back and forth). The length in a single direction was increased progressively by 1 m at every level. Each stage consisted of 5 repetitions of 12 s with a 6 s walking period between 2 lines set 2.5 m from the starting line. The running pace was dictated by a pre-recorded audio system (Da Silva et al., 2011; Teixeira et al., 2014). The test ended when participants failed to follow the audio cues on the front line for two successive repetitions (objective criteria observed by researchers). The last stage speed (PS_{T-CAR}) during the T-CAR was retained to allow the individualization of the distance covered during the intermittent shuttle-run exercise protocol (12 s shuttle-run/12 s pause) used herein.

High-Intensity Intermittent Exercise Session

Players completed a standardized warm-up consisting of a 5-min run at 50% of PS_{T-CAR} followed by 3 min of passive recovery before starting the HIIE model. Players performed three sets of 5-min bouts interspersed with 3 min of passive recovery between sets. Players performed repeated bouts of 12 s shuttle-runs (with a change of direction every 6 s) at 100% PS_{T-CAR} alternating with 12 s of passive rest until the completion of the 5 min established for each running set. The average running pace performed by the players between the start and return lines was dictated by a prerecorded audio cue, emitting beeps every 6 s. The distance covered by each player during the training sessions was individualized according to their respective 100% PS_{T-CAR}.

Statistical Analysis

Results are expressed as means ± SDs. After visual inspection, the Shapiro–Wilk test was used to verify the data normality. Levene's test was used to test if the homogeneity of variance was assumed. The inter-subject coefficient of variation (CV) was calculated for the %VO_2peak, %HRpeak, [La], and RPE in each running set of the HIIE model. Paired Student's *t*-test was used to examine the differences between T-CAR protocols performed on the grass and sand training surfaces for HRpeak, [La], RPE, and ground stiffness. A mixed model analysis was used to compare acute physiological responses between the HIIE model conducted on each training surface (SAND and GRASS), assuming the training surface (SAND or GRASS) and running sets (set 1, set 2, and set 3) as fixed factors, and the participants as a random factor. When a significant F-value was obtained, a *post-hoc* test with a Bonferroni adjustment was performed for multiple comparisons. The magnitude of the differences was assessed using standardized mean differences (Cohen's *d* effect size, ES) with thresholds of 0.20, 0.60, 1.20, 2.0, and 4.0 for small, moderate, large, very large, and extremely large (Batterham and Hopkins, 2006). Statistical analyses were carried out using SPSS statistical analysis software (SPSS version 17.0, Chicago, IL, United States). The level of significance was set at $p \leq 0.05$.

RESULTS

The depth of CPD penetration into the ground was significantly lower ($t = -14.092$, $p < 0.001$, $d = 2.23$) on GRASS (21.96 ± 10.53 mm) than for SAND surface (49.40 ± 13.90 mm), suggesting that the GRASS was a firmer surface than SAND.

After the completion of the T-CAR protocol, HRpeak ($t = 0.236$, $p = 0.821$, $d = 0.16$), [La] ($t = -0.403$, $p = 0.701$, $d = 0.16$) and RPE ($t = -1.000$, $p = 0.356$, $d = 0.43$) values did not differ between ground surfaces. The PS_{T-CAR} was significantly lower ($\Delta = -8.41 \pm 6.21\%$, $t = 3.745$, $p = 0.010$, $d = 1.58$) on SAND than for GRASS surface (**Table 1**).

The analysis of HIIE did not reveal a significant condition-by-time interaction for %VO_2peak ($F = 0.099$, $p = 0.906$), %HRpeak ($F = 0.029$, $p = 0.971$) and RPE score ($F = 0.232$, $p = 0.795$) nor a significant main effect of time ($F = 2.440$, $p = 0.111$) for %VO_2peak. A significant main effect of condition ($F = 56.592$, $p < 0.001$, $d = 2.29$) was found for %VO_2peak, with SAND eliciting a significantly higher %VO_2peak than for GRASS (**Figure 1A**).

%HRpeak and RPE values were significantly influenced by the type of surface [%HRpeak ($F = 16.239$, $p < 0.001$, $d = 1.04$); RPE ($F = 79.792$, $p < 0.001$, $d = 1.87$)] and training sets [%HRpeak ($F = 9.223$, $p = 0.001$); RPE ($F = 24.803$; $p < 0.001$)]. *Post-hoc* tests identified that cardiovascular and perceptual responses ($p < 0.001$) were significantly higher on SAND than on GRASS. Compared with set 1, %HRpeak during set 2 and set 3 was significantly ($p < 0.001$) higher irrespective of the surface conditions. Differences across the sets were moderate to large ($d = 1.22$, 1.69, and 0.62) and moderate ($d = 0.54$, 0.86, and 0.88) for SAND and GRASS conditions, respectively (**Figure 1B**). The RPE progressively increased over the sets in both surfaces (Set 1 < Set 2 < Set 3). The resulting ES ranged from moderate to very large ($d = 0.83$–3.16 and $d = 0.89$–2.38 for SAND and GRASS, respectively) (**Figure 1D**).

There was a significant condition-by-time interaction effect for [La] ($F = 4.110$, $p = 0.035$) with significantly higher [La] values for the SAND condition (set 1: $p = 0.003$, $d = 2.31$; set 2: $p = 0.001$, $d = 2.77$; set 3: $p < 0.001$, $d = 3.30$). Increments in [La] from sets 1–2 [$\Delta = 4.2 \pm 2.1$ mmol/L ($p = 0.017$, $d = 1.84$) vs. $\Delta = 1.8 \pm 0.9$ mmol/L ($p = 0.033$,

TABLE 1 | Descriptive statistics (mean ± DP; and range) for physiological, metabolic, perceptual, and peak speed reached during the Carminatti's test performed on GRASS and SAND training surfaces.

	GRASS			SAND		
		Range			Range	
	Mean ± DP	Min	Max	Mean ± DP	Min	Max
VO_2peak (mL/kg/min)	52.15 ±2.89	47.94	55.67	n.a	n.a	n.a
Hrpeak (bpm)	198.0 ±5.0	194.0	206.0	197.0 ±8.0	191.0	208.0
PS_{T-CAR} (km/h)	15.23 ±0.80*	14.00	16.20	13.89 ±0.89	12.20	14.70
[La] (mmol/L)	8.85 ±2.14	5.64	12.90	9.15 ±1.59	7.17	12.00
RPE (a.u.)	8.00 ±0.58	7	9	8.29 ±0.76	7	9

VO_2peak, peak oxygen consumption; HRpeak, peak heart rate; PS_{T-CAR}, peak speed reached at the end of Carminatti's test; [La], blood lactate concentration; RPE, rating of perceived exertion; n.a, not assigned.
**Significantly different from SAND surface ($p = 0.010$).*

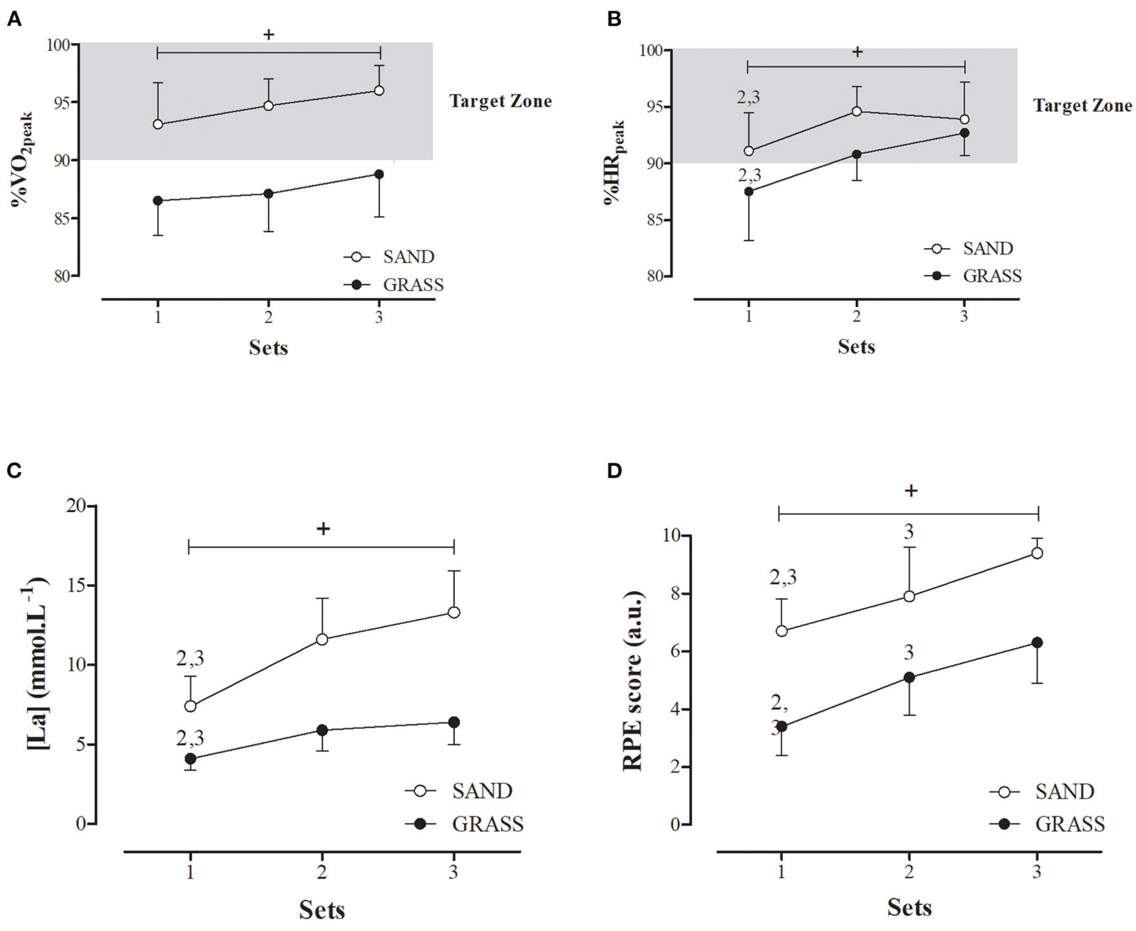


FIGURE 1 | VO_2 **(A)**, HR **(B)**, blood lactate [La] **(C)**, and RPE **(D)** responses to shuttle-run high-intensity intermittent exercise (HIIE) performed at 100% PS_{T-CAR} on SAND and GRASS surface condition. +: Denotes significant between-condition differences; 2: indicates a significant difference in relation to the second set; 3: indicates a significant difference in relation to the third set.

$d = 1.72$)] and sets 1–3 ($\Delta = 5.9 \pm 2.7$ mmol/L ($p = 0.001$, $d = 2.59$) vs. $\Delta = 2.3 \pm 0.9$ mmol/L ($p = 0.011$, $d = 2.08$)] were significantly greater on SAND than on GRASS surface, respectively (**Figure 1C**).

A low inter-subject CV for cardiorespiratory responses (VO_2 and HR) was observed during the HIIE session performed on SAND (%VO_2peak: 2.31–3.92%; %HRpeak: 2.31–3.78%) and GRASS (%VO_2peak: 3.47–4.12%; %HRpeak: 2.18–4.91%).

On the other hand, a higher inter-subject CV was noticed for metabolic and perceptual responses on SAND ([La]: 19.28–25.98%; RPE: 5.67–16.57%) and GRASS ([La]: 16.92–22.97%; RPE: 21.96–28.46%) conditions.

DISCUSSION

This is the first study that investigated the effects of SAND vs. GRASS training surfaces on internal load (i.e., VO_2, HR, RPE, and [La]) during a HIIE session performed at 100% PS_{T-CAR} in junior male soccer players. The results showed that the SAND condition elicited significantly higher %VO_2peak, %HRpeak, RPE, and [La] values than GRASS training surface, thus not confirming this study work hypothesis.

In the present study, the peak values of HR, [La], and RPE after the completion of T-CAR protocol did not differ between both training surfaces, with trivial to small ES (**Table 1**). On the other hand, PS_{T-CAR} was, on average, 8.4% slower on SAND than on GRASS surface. These findings are similar to those reported by Cetolin et al. (2010) who also demonstrated a lower PS_{T-CAR} (−7.0%) at the end of the T-CAR performed on SAND compared with GRASS surface. Running on SAND is characterized by a lower horizontal take-off velocity and a subsequent shorter forward distance traveled during the flight phase of the stride, which directly implies a reduced stride length, especially in the highest running speeds (Pinnington et al., 2005; Alcaraz et al., 2011; Gaudino et al., 2013). These movement pattern changes in association with a higher running cost may explain the observed lower PS_{T-CAR} in the SAND condition (Zamparo et al., 1992; Pinnington and Dawson, 2001a,b; Gaudino et al., 2013). Indeed, previous research showed that SAND demanded significantly higher VO_2 and [La] values than running on GRASS at comparable speeds, thus resulting in a steeper slope in the VO_2 and [La] vs. running speed relationship (Pinnington and Dawson, 2001b). However, possible inferences regarding the energy contribution during the T-CAR should be interpreted with caution, since neither the present nor the previous study of Cetolin et al. (2010) measured VO_2 responses during submaximal T-CAR speeds on SAND surface. Thus, future studies should further elucidate the extent to which these aforementioned aspects and other potential factors (e.g., peripheral fatigue) contribute to the slower PS_{T-CAR} observed in SAND.

The reported significant and practically large differences in PS_{T-CAR} and the non-significant correlation ($r = 0.382$; $p = 0.398$) between GRASS and SAND conditions strongly suggest test condition specificity. This means that those players who perform better on GRASS will not necessarily be the ones who perform better on SAND. This finding has practical relevance for strength and conditioning coaches when programming HIIE sessions on different training surfaces. For instance, the use of PS_{T-CAR} determined on GRASS as the reference speed for prescription of sand-based HIIE protocols could be problematic, since players would be exercising at a supramaximal intensity and, in turn, the same set duration prescribed for GRASS surface could not be sustained by the players when running on SAND. In addition, the distinct relative external load experienced by the players could impose a divergent workload, contributing to a wider variability in the response of the athlete to the training stimulus. Interestingly, the use of surface-specific relative training speeds (i.e., PS_{T-CAR}) resulted in a low inter-subject CV in the cardiorespiratory responses (VO_2 and HR) during the HIIE protocol performed on both SAND and GRASS surfaces (see section Results). Thus, it was possible to ensure a similar internal training load to all the players in each training surface condition using PS_{T-CAR} as the reference speed for training prescription, at least while considering the cardiorespiratory responses. The inter-subject CV for [La] in our study was similar to that found by Julio et al. (2020) (CV: 18–28%) using the anaerobic speed reserve as a parameter to calibrate exercise intensity. These data highlight the applicability of PS_{T-CAR} as an accurate metric to individualize exercise intensity (i.e., running distance) during shuttle-run-based HIIE sessions in male soccer players.

The acute physiological responses during the HIIE model were surface-specific. Indeed, the average HR, VO_2, RPE, and [La] values were 1.04-, 1.08-, 1.62-, and 1.96-fold higher, respectively, on SAND compared with those on GRASS. Moderate-to-large differences were found between surfaces for the physiological outcomes considered. Our findings are in agreement with those reported in other studies that also showed a higher demand in terms of cardiorespiratory, metabolic, and perceptual responses on SAND compared with GRASS using similar absolute running speeds (Pinnington and Dawson, 2001a,b; Binnie et al., 2013a,b, 2014b). Although the reasons for these aforementioned physiological, metabolic, and perceptual differences are not completely elucidated in the literature, some factors can aid to explain the findings of this study. From a biomechanical perspective, a more flexed hip and knee position associated with a greater muscle activation has been reported to support body mass and to stabilize lower limbs joints during the support phase of the stride when running on SAND (Pinnington et al., 2005). The resulting alteration in running kinematics and associated greater muscle recruitment may be considered as the possible cause of the greater cardiovascular and metabolic load (i.e., EC) of SAND running. The changes of direction of the sand-based HIIE model used here also deserve attention. Gaudino et al. (2013) found more intense maximum deceleration activities on SAND compared with those on GRASS surfaces during shuttle-sprint efforts. Thus, it could be speculated that the increased energetic demand verified on SAND might be, in part, related to the more intense deceleration movements required in our HIIE protocol performed on SAND. In addition, the greater muscle work when running on SAND (Pinnington et al., 2005) due to the longer foot contact time (Lejeune et al., 1998; Gaudino et al., 2013) may also have increased the EC to re-accelerate after each change of direction compared with the GRASS condition. Indeed, accelerating on SAND was reported to require a 30% extra EC compared with the GRASS condition (Gaudino et al., 2013). However, further studies are necessary to better understand the contribution of acceleration and deceleration movements to the increased energy demand during shuttle-run-based HIIE sessions when performed on SAND.

The time spent at intensities equal to or higher than 90% of VO_2peak or HRpeak plays a pivotal role in the aerobic adaptive responses to training (Castagna et al., 2011, 2013). For this reason, the time spent at high intensity has been reported as the variables conditioning HIIE effectiveness (Buchheit and Laursen, 2013a). Interestingly, SAND promoted a higher permanence at or above the reported effective HIIE intensity. With regard to [La], the values over sets were classified as high to very high for SAND, and low for GRASS surface (Buchheit and Laursen, 2013b). Similarly, players perceived HIIE session as harder on SAND (RPE > 7.0 a.u.) than on GRASS surface (3.0 < RPE < 7.0 a.u.) Interestingly, the considered bout duration and work-to-rest ratio (i.e., 12 s and 1:1) were not effective to warrant values above 90% of VO_2peak and HRpeak on GRASS condition (**Figure 1**). In an earlier study (Da Silva et al., 2015), players achieved HR values between 90 and 95% of HRpeak during the same HIIE protocol outlined here (12 s:12 s) when performed on GRASS surface, but considering four sets of 4 min. However, a slightly lower cardiovascular demand (85–90% of HRpeak) was observed with shorter running bouts (i.e., 6 s at 100% PS_{T-CAR}) (Da Silva et al., 2015). Even so, the two HIIE formats (12 s:12 s or 6 s:6 s) proved to be an efficient training stimulus to improve some aerobic fitness measures (e.g., anaerobic threshold and running speed at VO_2peak) and PS_{T-CAR} during the preseason phase in male junior soccer players (Da Silva et al., 2015). Nonetheless, changes in VO_2peak were negligible in the cited study conducted by Da Silva et al. (2015). These results may be associated with the short duration of the training program (only 5 weeks), but also with the "low" VO_2 demand (mean values below 90% VO_2peak) on GRASS elicited by the proposed HIIE protocol (i.e., a work-to-rest ratio of 1:1).

Understanding that the training process is planned from an integrative and multicomponent perspective, coaches and sports scientists should also consider the potential of SAND-based training as a means of developing some power-speed-related capacities in team-sport players. A recent systematic review with meta-analysis showed that sand and hard surface training interventions were similarly effective at improving both jump and sprint performances in team-sport players (Pereira et al., 2021). The authors argue that these neuromuscular performance adaptations displayed in both surfaces are underlined by two distinct—but possibly complementary—mechanisms. While the performance adaptations provided by hard surfaces may be more related to the improvement in the stretch-shortening cycle efficiency, on sand surfaces they seem to be more attributable to changes in muscle contractile properties (Pereira et al., 2021). Taking into account the high neuromuscular load required during shuttle-run (Gaudino et al., 2013) along with the increased muscle activation level observed on sand surface (Pinnington et al., 2005), future studies are encouraged to investigate the potential effectiveness of sand-based HIIE programs involving shuttle-run on jump and speed performance in soccer players and other team-sport players.

Some limitations should be addressed. First, due to logistical reasons, respiratory gas exchange measures (e.g., VO_2 response) were not evaluated during the T-CAR protocol performed on SAND, which prevented the comparisons of VO_2peak and VO_2-speed relationship between both training surfaces. In addition, submaximal responses of HR for the same running speed during T-CAR in both surfaces were also not recorded. Second, the lack of VO_2 responses during T-CAR on SAND also limited the interpretation of VO_2 demand during the HIIE in this specific surface, as the relative VO_2 values achieved during the sand-based HIEE session were expressed in function of VO_2peak observed on GRASS condition. Third, physical demand in terms of acceleration and deceleration movements during our HIIE protocol were not quantified. Fourth, despite the wide use of HR for soccer training prescription, it is important to recognize that this variable has some limitations for monitoring activities in an intermittent regime (Buchheit and Laursen, 2013a).

Practical Applications

The originality of this study lies in addressing specific acute physiological responses (VO_2, HR, [La], and RPE) to the training surface (SAND and GRASS) during a HIIE protocol performed at the same relative exercise intensity (i.e., 100% PS_{T-CAR}) in male soccer players. Another strength of this study was the applicability of PS_{T-CAR} as an accurate metric to individualize exercise intensity (i.e., running distance) during the HIIE model in the SAND and GRASS training conditions. From a practical standpoint, strength and conditioning coaches should pay attention to why players did not achieve VO_2 values above 90% of their individual VO_2peak during the HIIE session performed on the GRASS surface. This suggests that some adjustments in training variables (e.g., increase work-to-rest ratio or running bout and set duration) may be necessary to allow a high percentage of time spent above 90% of VO_2peak during HIIE session at 100%PS_{T-CAR} performed on the grass surface. Another suitable and practical alternative supported by this study is replacing the GRASS surface with SAND-based exercises. The sand-based HIIE session outlined here has a great potential to maximize gains in VO_2peak and aerobic running performance in the initial phases of the season (i.e., preseason), since this training stimulus elicited a higher cardiorespiratory load and anaerobic glycolytic contribution. In addition, a prior research that compared several energetic and biomechanical parameters of sprinting between SAND and GRASS (natural and artificial) has suggested that shuttle-run exercises might be a better strategy to generate more intense deceleration actions in a softer surface, such as SAND (Gaudino et al., 2013). Given that soccer is a sport with a greater frequency of high- and very–high-intensity decelerations compared with accelerations (Harper et al., 2019), the presence or absence of changes of direction should be taken into account during the HIIE programming in order to manage the eccentric workload that will be experienced by the players in this type of activity performed on SAND.

CONCLUSIONS

This study showed that the SAND surface elicited a higher internal workload in terms of cardiorespiratory, metabolic, and perceptual response than the GRASS surface during a single HIIE session performed at the same relative exercise intensity (i.e., 100%PS_{T-CAR}). Furthermore, PS_{T-CAR} can be used as an accurate reference speed to individualize the running distance during HIIE with short intervals either in the SAND or in the GRASS condition.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Research Ethics Committee of the Federal University of Santa Catarina (Number 459.431). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

TC, JS, and LG participated in the conception and design of the study. TC, JS, and AH participated in the data collection. AT, FN, and CC participated in the data analysis and interpretation. All authors participated sufficiently in the work drafting the study and/or revising it critically and approved the final version to be published.

FUNDING

This study was financed by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES)—Finance Code 001.

ACKNOWLEDGMENTS

The authors are grateful to the players, coaches, and technical staff for their engagement in this study.

REFERENCES

Alcaraz, P., Palao, J., Elvira, J., and Linthorne, N. (2011). Effects of a sand running surface on the kinematics of sprinting at maximum velocity. *Biol. Sport.* 28, 95–100. doi: 10.5604/942737

Batterham, A. M., and Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *Int. J. Sports Physiol. Perform.* 1, 50–57. doi: 10.1123/ijspp.1.1.50

Binnie, M., Dawson, B., Arnot, M., Pinnington, H., Landers, G., and Peeling, P. (2014a). Effect of sand versus grass training surfaces during an 8-week pre-season conditioning programme in team sport athletes. *J. Sports Sci.* 32, 1001–1012. doi: 10.1080/02640414.2013.879333

Binnie, M., Dawson, B., Pinnington, H., Landers, G., and Peeling, P. (2014b). Sand training: a review of current research and practical applications. *J. Sports Sci.* 32, 8–15. doi: 10.1080/02640414.2013.805239

Binnie, M. J., Dawson, B., Pinnington, H., Landers, G., and Peeling, P. (2013a). Effect of training surface on acute physiological responses after interval training. *J. strength Cond. Res.* 27, 1047–1056. doi: 10.1519/JSC.0b013e3182651fab

Binnie, M. J., Dawson, B., Pinnington, H., Landers, G., and Peeling, P. (2013b). Part 2: effect of training surface on acute physiological responses after sport-specific training. *J. strength Cond. Res.* 27, 1057–1066. doi: 10.1519/JSC.0b013e3182651d63

Buchheit, M. (2008). The 30-15 intermittent fitness test: accuracy for individualizing interval training of young intermittent sport players. *J. strength Cond. Res.* 22, 365–374. doi: 10.1519/JSC.0b013e3181635b2e

Buchheit, M., and Laursen, P. (2013a). High-intensity interval training, solutions to the programming puzzle. Part I: cardiopulmonary emphasis. *Sport. Med.* 43, 313–338. doi: 10.1007/s40279-013-0029-x

Buchheit, M., and Laursen, P. (2013b). High-intensity interval training, solutions to the programming puzzle. Part II: anaerobic energy, neuromuscular load and practical applications. *Sport. Med.* 43, 927–954. doi: 10.1007/s40279-013-0066-5

Buchheit, M., Millet, G. P., Parisy, A., Pourchez, S., Laursen, P. B., and Ahmaidi, S. (2008). Supramaximal training and postexercise parasympathetic reactivation in adolescents. *Med. Sci. Sports Exerc.* 40, 362–371. doi: 10.1249/mss.0b013e31815aa2ee

Castagna, C., Impellizzeri, F. M., Chaouachi, A., Bordon, C., and Manzi, V. (2011). Effect of training intensity distribution on aerobic fitness variables in elite soccer players: a case study. *J. Strength Cond. Res.* 25, 66–71. doi: 10.1519/JSC.0b013e3181fef3d3

Castagna, C., Impellizzeri, F. M., Chaouachi, A., and Manzi, V. (2013). Preseason variations in aerobic fitness and performance in elite-standard soccer players: a team study. *J. Strength Cond. Res.* 27, 2959–2965. doi: 10.1519/JSC.0b013e31828d61a8

Cetolin, T., Foza, V., Guilherme, L., Guglielmo, A., and Superior, E. (2010). Diferença entre intensidade do exercício prescrita por meio do teste TCAR no solo arenoso e na grama. *Braz. J. Kinathrop. Hum. Perform.* 12, 29–35. doi: 10.5007/1980-0037.2010v12n1p29

Da Silva, J. F., Guglielmo, L. G. A., Carminatti, L. J., De Oliveira, F. R., Dittrich, N., and Paton, C. D. (2011). Validity and reliability of a new field test (Carminatti's test) for soccer players compared with laboratory-based measures. *J. Sports Sci.* 29, 1621–1628. doi: 10.1080/02640414.2011.609179

Da Silva, J. F., Nakamura, F. Y., Carminatti, L. J., Dittrich, N., Cetolin, T., and Guglielmo, L. G. A. (2015). The effect of two generic aerobic interval training methods on laboratory and field test performance in soccer players. *J. Strength Cond. Res.* 29, 1666–1672. doi: 10.1519/JSC.0000000000000776

Davies, S. E. H., and Mackinnon, S. N. (2006). The energetics of walking on sand and grass at various speeds. *Ergonomics* 49, 651–660. doi: 10.1080/00140130600558023

Dupont, G., Akakpo, K., and Berthoin, S. (2004). The effect in-season, high-intensity interval training in soccer players. *J. Strength Cond. Res.* 18, 584–589. doi: 10.1519/00124278-200408000-00034

Floriano, L., Da Silva, J., Teixeira, A., Do Nascimento Salvador, P., Dittrich, N., Carminatti, L., et al. (2016). Physiological responses during the time limit at 100% of the peak velocity in the carminatti's test in futsal players. *J. Hum. Kinet.* 54, 91–101. doi: 10.1515/hukin-2016-0038

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., et al. (2001). A new approach to monitoring exercise training. *J. Strength Cond. Res.* 15, 109–115. doi: 10.1519/1533-4287(2001)015<0109:anatme>2.0.co;2

Gaudino, P., Gaudino, C., Alberti, G., and Minetti, A. E. (2013). Biomechanics and predicted energetics of sprinting on sand: hints for soccer training. *J. Sci. Med. Sport.* 16, 271–275. doi: 10.1016/j.jsams.2012.07.003

Harper, D. J., Carling, C., and Kiely, J. (2019). High-intensity acceleration and deceleration demands in elite team sports competitive match play: a systematic review and meta-analysis of observational studies. *Sports Med.* 49, 1923–1947. doi: 10.1007/s40279-019-01170-1

Impellizzeri, F. M., Rampinini, E., Castagna, C., Martino, F., Fiorini, S., and Wisloff, U. (2008). Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. *Br. J. Sports Med.* 42, 42–46. doi: 10.1136/bjsm.2007.038497

Julio, U. F., Panissa, V. L. G., Paludo, A. C., Alves, E. D., Campos, F. A. D., and Franchini, E. (2020). Use of the anaerobic speed reserve to normalize the prescription of high-intensity interval exercise intensity. *Eur. J. Sport Sci.* 20, 166–173. doi: 10.1080/17461391.2019.1624833

Lejeune, T., Willems, P., and Heglund, N. (1998). Mechanics and energetics of human locomotion on sand. *J. Exp. Biol.* 201, 2071–2080. doi: 10.1242/jeb.201.13.2071

Miyama, M., and Nosaka, K. (2004). Influence of surface on muscle damage and soreness induced by consecutive drop jumps. *J. Strength Cond. Res.* 18, 206–211. doi: 10.1519/00124278-200405000-00002

Pereira, L. A., Freitas, T. T., Marín-Cascales, E., Bishop, C., McGuigan, M. R., and Loturco, I. (2021). Effects of training on sand or hard surfaces on sprint and jump performance of team-sport players: a systematic review with meta-analysis. *Strength Cond. J.* 43, 56–66. doi: 10.1519/SSC.0000000000000634

Pinnington, H., Lloyd, D., Besier, T., and Dawson, B. (2005). Kinematic and electromyography analysis of submaximal differences running on a firm surface compared with soft, dry sand. *Eur. J. Appl. Physiol.* 94, 242–253. doi: 10.1007/s00421-005-1323-6

Pinnington, H. C., and Dawson, B. (2001a). Running economy of elite surf iron men and male runners, on soft dry beach sand and grass. *Eur. J. Appl. Physiol.* 86, 62–70. doi: 10.1007/s004210100472

Pinnington, H. C., and Dawson, B. (2001b). The energy cost of running on grass compared to soft dry beach sand. *J. Sci. Med. Sport* 4, 416–430. doi: 10.1016/S1440-2440(01)80051-7

Ramirez-Campillo, R., Álvarez, C., García-Pinillos, F., García-Ramos, A., and Loturco, I., Chaabene, H., et al. (2020). Effects of combined surfaces vs. single-surface plyometric training on soccer players' physical fitness. *J. Strength Cond. Res.* 34, 2644–2653. doi: 10.1519/JSC.0000000000002929

Teixeira, A. S., Da Silva, J. F., Carminatti, L. J., Dittrich, N., Castagna, C., and Guglielmo, L. G. A. (2014). Reliability and validity of the carminatti's test for aerobic fitness in youth soccer players. *J. Strength Cond. Res.* 28, 3264–3273. doi: 10.1519/JSC.0000000000000534

Zamparo, P., Perini, R., Orizio, C., Sacher, M., and Ferretti, G. (1992). The energy cost of walking or running on sand. *Eur. J. Appl. Physiol. Occup. Physiol.* 65, 183–187. doi: 10.1007/BF00705078

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

BRIEF RESEARCH REPORT
published: 02 August 2021
doi: 10.3389/fpsyg.2021.682059

Experience and Management of Fear in Men's World Cup Alpine Ski Racing

Morgan Rogers and David Paskevich*

Faculty of Kinesiology, University of Calgary, Calgary, AB, Canada

Alpine ski racers, specifically in the discipline of downhill, may experience fear competing in such a high-risk environment. The purpose of this study was to explore Canadian national team men's experience and management of fear in World Cup alpine ski racing. This study uses an interpretive phenomenological analysis, conducted with five male members of the Canadian national ski team. Three themes emerged: contextual influences, preparation and process, and risk vs. reward. The findings indicate one's experience and management of fear may be influenced by contextual factors (e.g., weather, course profile) and confidence, and that confidence is influenced by the same situational factors that influence fear as well as athlete preparation. There currently exists a discrepancy between the athletes' approaches to training and racing, making it difficult to master fear management strategies. As a result of the discrepancy created between training and racing, there are several implications for how the national team environment and training is structured, and we present recommendations for how these findings can be applied to training.

Keywords: fear, risk-taking, alpine skiing, performance, risk management, instrumental emotion regulation

OPEN ACCESS

Edited by:
Filipe Manuel Clemente, Polytechnic Institute of Viana Do Castelo, Portugal

Reviewed by:
Rui Sofia, University of Minho, Portugal
Marinella Coco, Università di Catania, Italy

****Correspondence:***
Morgan Rogers
morgan.rogers@ucalgary.ca

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *17 March 2021*
Accepted: *06 July 2021*
Published: *02 August 2021*

Citation:
Rogers M and Paskevich D (2021) Experience and Management of Fear in Men's World Cup Alpine Ski Racing. Front. Psychol. 12:682059. doi: 10.3389/fpsyg.2021.682059

INTRODUCTION

Olympic and World Cup alpine ski racers all push out of the start gate in pursuit of the same goal: to be the fastest person down the hill, and win the race. Pursuing this goal often involves risk taking and pushing personal limits, which, in the speed discipline of alpine ski racing (i.e., downhill, super-G) means athletes are in very dangerous situations, due to extreme speeds (e.g., exceeding 120 km/h) on steep and icy courses. Risk-taking to achieve performance goals, in an already dangerous situation, results in the potential for elite alpine ski racers to experience fear (ESPNW, 2018).

Smith and Lazarus (1993) conceptualize fear as an emotional response to circumstances where an individual feels threat or danger. Given the highly dangerous nature of alpine ski racing, with the possibility of crashes, injury, and in rare cases death, a World Cup or Olympic ski race can be viewed as a threat to personal safety. Therefore, in line with Smith and Lazarus (1993), who suggest that individuals facing threat to their well-being experience fear, it is possible that alpine ski racers are subject to experiencing fear when competing. Lazarus (1966) suggests that individuals appraise their environment relative to its implication for personal well-being. Appraisal serves to prepare individuals to cope by connecting emotional responses (e.g., fear) with goals (e.g., maximizing benefit or minimizing harm). Lazarus (1966) has outlined two levels of appraisal: (1) primary, where an individual assesses the circumstances relative to personal well-being; and (2) secondary, where an individual assesses their resources and options for coping. Smith and Lazarus (1993) further break down primary appraisal into two components, where an individual assesses whether their emotional response is relevant to their goals, and whether it is congruent with their goals. For an elite alpine ski racer experiencing fear, one might weigh whether their fear is relevant to their goal of skiing fast, and whether it is consistent with their goal of skiing fast.

Instrumental emotion regulation theory suggests that individuals are willing to experience unpleasant emotions (e.g., fear) when the emotion supports goal attainment (Tamir and Ford, 2009). Tamir and Ford (2009), in their virtual simulation experiment with undergraduate students, suggest that fear can be used as an instrumental emotion when engaging in tasks that are threatening. Therefore, an individual's primary appraisal of their fear could be driven in part by individual belief as to whether fear can be used instrumentally (Smith and Lazarus, 1993; Tamir and Ford, 2009). Instrumental emotion regulation has been examined in sport, with Lane et al. (2011) studying instrumental emotion regulation with a survey of 360 runners, finding that 15% of participants felt experiencing anger or anxiety enhanced their performance. In qualitative studies of extreme sports, study participants have shared that when pursuing highly dangerous sports, fear may actually be a necessary emotion, as it ensures a safe course of action (Brymer and Schweitzer, 2012).

While there has been minimal research concerning the experience of fear in competitive athletes, the extreme sport literature (e.g., BASE jumping, big mountain free skiing) provides an understanding of how individuals experience fear in high-risk sports (Slanger and Rudestam, 1997; Brymer and Oades, 2007; Llewellyn et al., 2008; Brymer and Schweitzer, 2012; Buckley, 2016). In the extreme sport literature, fear is typically presented as an emotional response in anticipation of risk-taking behavior. When examining risk-taking in extreme sport settings, athletes' risks are calculated, based on years of experience in the sport and extensive preparation (Brymer and Mackenzie, 2017). In Brymer and Oades' 2007 study of extreme sport athletes, one BASE jumper shared that when deciding to jump, they balanced fear with their knowledge of personal capabilities and technical prowess. Brymer and Mackenzie (2017) further suggested that using the term "risk-taking" may not be appropriate when judging an athlete's choices from the outside. They believe that extreme sport athletes are very well-prepared, highly skilled, and know their limits from years of pushing them, culminating in the athlete's behavior not being viewed as a risk, but rather, a calculated and informed decision.

In Brymer and Schweitzer's 2012 phenomenological study of fear in extreme sport, a participant stated that even with extensive experience, high-risk situations result in fear. However, the participant further stated that fear experienced garners a respect for the situation. This is important to recognize, because it positions fear as a healthy and necessary emotion, with respect for the situation creating awareness for potential dangers and ensuring a safe course of action. Therefore, it is important to recognize that athletes in high-risk sports do experience fear, but it can be managed so that it is facilitative and used to support goal attainment (Brymer and Schweitzer, 2012; Lane et al., 2011). The literature suggests that there are individual differences in how fear is appraised and how an athlete uses unpleasant emotions instrumentally (e.g., fear, anxiety) to facilitate goal attainment. Therefore, the purpose of this study was to explore Canadian national team men's experience and management of fear in World Cup alpine ski racing.

METHODS

Participants

Participants were five members of the men's Canadian National Alpine Ski Team, who train and compete in the speed disciplines of Downhill and Super-G, and were aged 24 to 37 ($M = 31.0$, SD $= 4.95$). Participants had 3–16 years of experience on the World Cup Circuit ($M = 9.8$, SD $= 5.22$), and had all competed at the Olympic games (International Ski Federation, 2019). Participants were selected using a purposive sample, based on the criteria that they (a) were members of the Canadian national team competing in the speed discipline, and (b) had competed on the World Cup Circuit (Smith, 2017). The authors' university ethics board approved this study. All participants provided informed consent prior to partaking in the study.

Procedure

Interview Procedure

The interview guide was 11 questions long, and included broad, open-ended questions such as (a) "What are the signs that indicate you are experiencing fear?" (b) "What are your current strategies to manage fear?" and (c) "How do you experience and manage your arousal before your run compared to during your run?"

A strength of interviewing is the trust and rapport built between participant and researcher (Fontana and Frey, 2000). Therefore, on a separate occasion prior to data collection, the first author attended the Alpine Canada's testing camp to meet participants and develop rapport, as well as outline the study. All participants were given detailed information about the study and an understanding that their data would be kept confidential.

Interviews were then conducted face-to-face by the first author at a training camp later in the year. The pre-season training period was selected for data collection in order to avoid asking questions about fear at or close to a race. Interviews were ∼10 minutes in length, providing two to three pages of single-spaced text per interview. While interviews were short in length, the author had previously established a trusting relationship with participants. Additionally, due to the constraints of accessing elite athletes for research (Odendahl and Shaw, 2001), and collecting data at a training camp, the interviews were conducted at the location where a competitor of the participants had died in a training accident 1 year earlier. Therefore, it is possible that the memory of this accident influenced participants' willingness to speak at length on the subject of fear.

Data Preparation and Analysis Procedures

Data preparation and analysis followed a series of steps guided by interpretive phenomenological analysis (IPA). First, all interviews were recorded and transcribed verbatim. Transcripts were sent to participants for member checking, and no modifications were made (Creswell and Creswell, 2018). In line with the practice of IPA, analysis began with familiarization of each transcript as a single case. Each transcript was read and re-read, with initial notes and codes identified. These initial codes were then discussed between the two authors, grouped, and translated into themes (Sparkes and Smith, 2013; Smith, 2017).

Trustworthiness

Several steps were taken to ensure trustworthy data. First, to ensure credibility and confirmability, participants were sent their transcripts, where four participants did not comment, and one confirmed the transcript "looks good!" (Creswell and Creswell, 2018). To ensure further credibility, the second author acted as a critical friend for the first author throughout data analysis, creating conversations that strengthened the overall analysis (Sparkes and Smith, 2013). Finally, to ensure transferability, a thick description was used, which emphasizes using participant quotes to illustrate results (Tracy, 2010).

RESULTS

We outline three main themes: contextual influences, preparation and process, and risk vs. reward (see **Table 1**). Subthemes that emerged from contextual influences are: anticipatory anxiety, race day factors, and confidence.

Contextual Influences

Certain situations may result in the experience of fear, and racers will not be confident (i.e., a quality that facilitates fear management) in all situations. Fear primarily occurs as an anticipatory emotion prior to pushing out of the start gate, and can be triggered by several situationally specific factors. Conditions and courses can contribute to fear if skiing at a new venue or skiing terrain that doesn't match one's style of skiing. Finally, fear can emerge from situations where athletes have crashed or are returning from injury.

Anticipatory Anxiety

When fear is present, it is typically an anticipatory emotion experienced prior to starting a race. Once an athlete begins their run, there may not be room to experience fear. This sentiment can be seen in this statement from one of the skiers:

> The hardest part is definitely the arousal before, once you push out of the gate you generally get into a calm because you're able to do what you need to do. I think the hardest part is the anxiety of knowing that you need to do something but not being given the chance to do it just yet, and that gets into your head. So, it's just staying in the moment prior to the race to stay calm so you have more energy and more mental capacity when it's time to do what you need to do. (P5)

All skiers interviewed shared a similar response, that when in the run, the focus is on the present moment. With a focus on the present, and at high speeds, there is typically not room for experiencing fear while in the run, as echoed in the statement "there's not a lot of time to think during the run" (P2). Another skier shared "during the run everything just comes as it is…for me at least it's just instinct most of the time" (P3).

Race Day Factors

Conditions and courses are an important variable to consider, because they are an inherent part of the sport, and may incite fear or confidence. Different athletes carry varying skillsets that allow them to excel in certain conditions or on certain courses, and struggle in others. Additionally, when conditions or courses cause uncertainty skiers may experience increased levels of fear. For example, one athlete shared:

> Every variable is an added factor, like if you can't see obviously that's going to be scary, if you are unsure of the surface you're pushing your skis into that's another thing that could tack onto the variable of fear. (P2)

Another shared: "Any unknown track you always have a lot more fear at the beginning of that, if you've never gone down something before." (P3) Based on what emerged, it is evident that doubt may lead to fear, coming either as a result of an athlete's inability to manage courses or conditions that are not favorable, or from uncertainty. Another context specific variable that contributes to fear is an awareness of adverse events, such as watching competitors crash and returning from personal injury. This is reflected in the statement from one participant returning from injury:

> For me right now, I'm coming back from an injury, so I've been away from skiing for an entire year and I am struggling with that, it's not, I would say that it is fear actually. When you come back from an injury, your body knows what it wants to do, you know I want to charge…I want to be in an aggressive position, and there's something that just holds you back a little bit…it's just this mental block you have to push through and for some reason after a certain amount of time it releases and then you're able to attack and go after it again. (P4)

Confidence

Confidence is context specific, and in the moments where confidence is lacking, fear may be present. For participants, confidence was one of the most frequently cited skills used in

TABLE 1 | Results.

Theme		Example
Contextual influences	Anticipatory anxiety	Fear experienced prior to run, not during
	Race day factors	Weather and snow conditions
		Course profile
		Return from injury
	Confidence	Increased confidence aids in fear management
		Course profile suits athlete's skiing style
Preparation and process		High quality off-season training Established pre-competition and competition plans
Risk vs. Reward		Take greater risks in high-caliber races than in training

fear management. The following statement from one of the interviewees clearly articulates the importance of confidence for fear management: "when the confidence builds, I find the fear or anxiety dissipates and it's replaced by the feeling of being excited." (P4)

While courses and conditions can be a source of fear by causing uncertainty, they can also be a source of confidence for the athlete when favorable. Several athletes noted that when conditions were "fair" with "good visibility and the snow is consistent all the way down" (P2), it is easy to push and have the confidence to charge. In addition to favorable conditions, certain courses will suit an athlete's skiing style, and if they have success on a particular course they can carry that confidence next time they race that venue.

Preparation and Process

In the context of this study, preparation is considered all training or tasks undertaken to achieve top performance on race day. Training was the most cited tool related to preparation, and is purposefully scheduled. For example, the Canadian national ski team travels the world during the summer season for on-snow camps. Diverse locations are deliberately chosen in order to train on a variety of courses and snow conditions; the importance of which has been highlighted with the impact of courses and conditions on both confidence and fear. One skier shared this perspective on preparation in relation to fear:

> For us it's a not huge thing, I think it's more people looking in from the outside that are scared, like my mom is terrified but it's because she hasn't done the steps to prepare for everything we do. It's normal for us, so the fear is there, even for us looking in, I get more nervous watching other people, then you have to think, they've done everything to prepare as well. (P2)

While preparation is centered on training days, process is focused on race day. Process is the routine that a racer develops and works through each race day and what they focus on during the run. One skier interviewed shared the importance of having a routine because it provides consistency in an environment of constantly changing venues, courses, and conditions.

> It helps you to settle into a routine so from there it's just repetitions instead of this is new, today race day, everything's different everything's throwing me off, so I think by having a planned scheduled routine that you practice many times it helps a lot. (P4)

As noted in the contextual influences section, uncertainty may contribute to the experience of fear, and having a routine can significantly minimize uncertainties and aid in arousal management. Grant and Schempp (2013) found that utilizing a pre-competition plan allows athletes to maintain focus on things that are within their control, rather than worrying about factors out of their control. One of the interviewed skiers shares the importance of routine both as a fear management and confidence building strategy:

> I think that being prepared in general helps a lot. I have a routine that I try and stick to so if I want to do well on race day the first thing I do in the morning is I wake up and I try to be in a good mood and not eat a lot of energy. Then I go through my routine, I have a plan for when I go free skiing what I want to work on, I have a plan for when I go through inspection, and I think that helps.
>
> How do you get confidence? I mean it's tough to turn it on 1 day and just say I want to be confident, so I think there's a build-up process to that and again I think it has to do with routine, you go out there day after day, you kind of chip away at it, you get better, and as you get better your confidence builds. (P4)

Risk vs. Reward

Risk vs. reward is also influenced by context. Participants shared they are more inclined to take big risks when there is an equivalent reward, and without an external reward, they may not take risks. For example, all racers stated that they would take their biggest risks at events such as the Olympics, World Championships, or Kitzbühel. Athletes are willing to take bigger risks at these three events because they are the most prestigious events in alpine skiing, and therefore carry the biggest reward for risks taken. It was also unanimous that taking risks in training was not worth it. This collective approach to risk-taking is summarized in the following quotes:

> I mean for sure the bigger events I'm more willing to push my limits a lot more, because the reward is bigger. So, it's risk vs. reward a lot of the time. I tend, I as get older especially, I have a harder time to push it in training I find, and I think that's partially because there is no reward for it, other than improving, but it's not like you get to the bottom and there's a medal waiting for you, there's World Cup points, there's prize money—there's none of that. So, it's not worth the risk to take these chances and risk it like maybe a young guy would because he's trying to prove himself to try and get a spot on the team. So, in my age I'm looking more for big events like World Cups or the World Championships. (P4)
>
> Usually the bigger races are when I like to step up and risk everything as much as possible, I really don't like risking anything at all in training…big races like Kitzbühel, World Champs, Olympics—I thrive on how much they're built up. (P1)

As seen in the above quotes, the participants have intentionally selected the moments when they will take risks—based on when matters the most to them. Selectively going all in for the most important races is the epitome of the risk vs. reward attitude, and when the racers decide it's worth it and take that risk, there is no holding back. When interviewees were asked about their own risk management strategies, a common sentiment was "my current risk management strategy would be to risk it all—no safety anymore." (P5) However, it is important to keep this response grounded in a racing context where risk is on the table. Flørenes et al. (2009) note that in World Cup alpine skiing, the majority of injuries occurred in races, while the least number of injuries occurred in training, which supports this finding that athletes typically take big risks in races. Interestingly, some participants made contradictory statements regarding risk within their interview, which could have implications for how athletes are training and racing, seen in this quote:

> Treat it [racing] like every normal day because we do a lot more training than racing and I feel like trying to treat races differently is a recipe for disaster, because they're so far and few between whereas we train tons and tons of days every single year. (P3)

This athlete, like others, had also shared that for any run outside of a World Cup or Championship race, they would not "take any unnecessary risks." These two quotes highlight an inconsistent philosophy for racing. The risk vs. reward approach is largely based on extrinsic, material rewards and has created a discrepancy between training and racing, which may result in different experiences of fear in the two settings.

DISCUSSION

The major accordance between this study and the extreme sport literature is that athletes participating in high-risk sports do experience fear, but are able to manage their fear to perform their sport (Brymer and Oades, 2007). However, in contrast to the extreme sport literature, study participants did not speak to using fear to ensure safety or enhance performance. This finding aligns with the work of Lane et al. (2011), who found that while some athletes use unpleasant emotions for performance enhancement the majority (i.e., 85%) do not. While the participants in the present research did not speak the instrumental use of fear, it is still present in elite alpine ski racing. For example, when a Canadian Olympian in alpine skiing retired from competition, he shared with the media that his decision was brought on in part by a teammate's crash and subsequent airlift from the ski hill. His statement to the media demonstrates fear being used instrumentally to make a decision: "[when my teammate] crashed, I thought 'I should just take the chairlift down.' It took everything for me to push out of the start gate" (Sportsnet, 2018).

In line with self-efficacy theory, which describes situation specific confidence, participants in the present research relied on their confidence to manage their fear (Bandura, 1977). Athletes specifically spoke to using the strongest source of self-efficacy, past performance success, as a means of bolstering their confidence, managing fear, and ultimately taking greater risks to achieve their performance goals. However, it becomes difficult to rely on past performance success to support fear management if the opportunities to experience and manage fear are infrequent, due to the limited risk-taking noted by participants. Therefore, if athletes do not want to push their limits in training, due to the high injury risk, they must find another way to experience and manage fear, in order to boost their confidence in their ability to do so. One potential option for doing this, and a future direction of study, is the use of virtual reality (VR) to train fear management. Nuderscher and Buchheim (2019) note that stress generated with VR is comparable to stress generated *in vivo*, and VR is a promising area for the development of stress management skills.

Coaches and sport psychology practitioners should work with athletes to create an environment that supports safe risk taking, and develops fear management strategies. Building on the preparation section in the results, coaches should continue to thoughtfully plan training so athletes can train on a variety of courses and conditions, train well in the gym to mitigate injury risk (Jordan et al., 2017), and work with ski technicians to ensure athletes have a ski fleet they on confident skiing on (M. Rufener, personal communication, June 1, 2019). Additionally, sport psychology practitioners should work with athletes to help them develop fear management strategies, including self-efficacy, the use of fear as an instrumental emotion, and potentially implementing a VR intervention.

A limitation of the present study is the length of the interviews and limited transferability of results to ski racers of other nations and genders. Future research should conduct interviews in the summer training season at a venue physically removed from ski competition, and should include participants from other nations and genders.

Study results and practical implications are important for use by coaches and support staff of elite alpine skiers when developing a training program. It is important to consider how performance is impacted when athletes train differently than they race, and how training can be structured to be more reflective of racing. Several ways to do so have emerged in this study; such as creating an environment that supports safe risk-taking, and the development of fear management strategies.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available in order to protect participant privacy. Requests to access the datasets should be directed to Morgan Rogers, morgan.rogers@ucalgary.ca.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Calgary Conjoint Health Research Ethics Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MR and DP conceptualized the study, created the interview guide, and analyzed the data. MR collected the data and wrote the manuscript. DP provided critical revisions and edits on the manuscript. Both authors approved the manuscript in final form.

ACKNOWLEDGMENTS

Thank you to Alpine Canada staff and athletes for their support of this research.

REFERENCES

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioural change. *Psychol. Rev.* 84, 191–215. doi: 10.1037/0033-295X.84.2.191

Brymer, E., and Mackenzie, S. (2017). "Psychology and the extreme sport experience," in *Extreme Sports Medicine*, ed F. Feletti (Cham: Springer International Publishing), 3–13.

Brymer, E., and Oades, L. G. (2007). Extreme sports a positive transformation in courage and humility. *J. Humanist. Psychol.* 49, 114–126. doi: 10.1177/0022167808326199

Brymer, E., and Schweitzer, R. (2012). Extreme sports are good for your health: a phenomenological understanding of fear and anxiety in extreme sport. *J. Health Psychol.* 18, 477–487. doi: 10.1177/1359105312446770

Buckley, R. C. (2016). Qualitative analysis of emotions: fear and thrill. *Front. Psychol.* 7:1187. doi: 10.3389/fpsyg.2016.01187

Creswell, J. W., and Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. Thousand Oaks, CA: SAGE Publications, Inc.

ESPNW (2018). *"There Are Atletes Who Say, 'I Have No Fear.'... I Call B.S." —@MikaelaShiffrin". Twitter, video, February 14, 2018*. Available online at: https://twitter.com/espnw/status/963933780124798977?lang=en (accessed April 20, 2020).

Flørenes, T. W., Bere, T., Nordsletten, L., Heir, S., and Bahr, R. (2009). Injuries among male and female world cup alpine skiers. *Br. J. Sports Med.* 43, 973–978. doi: 10.1136/bjsm.2009.068759

Fontana, A., and Frey, J. H. (2000). "The Interview: from structured questions to negotiated text," in *Handbook of Qualitative Research*, eds N. K. Denzin and Y. S. Lincoln (Thousand Oaks, CA: Sage), 61–105.

Grant, M. A., and Schempp, P. G. (2013). Analysis and description of olympic gold medallists' competition-day routines. *Sport Psychol.* 27, 156–170. doi: 10.1123/tsp.27.2.156

International Ski Federation (2019). *Biographies*. Available online at: https://www.fis-ski.com/DB/alpine-skiing/biographies.html (accessed April 30, 2019).

Jordan, M. J., Aagaard, P., and Herzog, W. (2017). Anterior cruciate ligament injury/reinjury in alpine ski racing: a narrative review. *Open Access J. Sports Med.* 8, 71–83. doi: 10.2147/OAJSM.S106699

Lane, A. M., Beedie, C. J., Devonport, T. J., and Stanley, D. M. (2011). Instrumental emotion regulation in sport: relationships between beliefs about emotion and emotion regulation strategies by athletes. *Scand. J. Med. Sci. Sports* 21, 445–451. doi: 10.1111/j.1600-0838.2011.01364.x

Lazarus, R. S. (1966). *Psychological Stress and the Coping Process.* New York, NY: McGraw Hill.

Llewellyn, D. J., Sanchez, X., Asghar, A., and Jones, G. (2008). Self-efficacy, risk taking and performance in rock climbing. *Pers. Individ. Diff.* 45, 75–81. doi: 10.1016/j.paid.2008.03.001

Nuderscher, K., and Buchheim, A. (2019). High risk sports, pyschology and virtual reality- "living on the edge." *Biomed. J. Sci. Tech. Res.* 24, 17894–17897. doi: 10.26717/BJSTR.2019.24.003984

Odendahl, T., and Shaw, A. (2001). "Interviewing elites," In *Handbook of Interview Research*, eds J. F. Gubrium and J. A. Holstein (Thousand Oaks: SAGE), 299–315.

Slanger, E., and Rudestam, K. E. (1997). Motivation and disinhibition in high risk sports: sensation seeking and self-efficacy. *J. Res. Pers.* 31, 355–374. doi: 10.1006/jrpe.1997.2193

Smith, B. (2017). "Narrative analysis in sport and exercise: how can it be done?" in *Routledge Handbook of Qualitative Research in Sport and Exercise*, eds B. Smith and A. Sparkes (New York, NY: Routledge), 260–273.

Smith, C. A., and Lazarus, R. S. (1993). Appraisal components, core relational themes, and the emotions. *Cogn. Emot.* 7, 233–269. doi: 10.1080/02699939308409189

Sparkes, A., and Smith, B. (2013). *Qualitative Research Methods in Sport, Exercise, and Health: From Process to Product*. New York, NY: Routledge.

Sportsnet (2018). *Decorated Canadian Alpine Skier Erik Guay Announces Retirement*. Available online at: https://www.sportsnet.ca/more/decorated-canadian-alpine-skier-erik-guay-announces-retirement/#:\sim:text=Decorated%20Canadian%20alpine%20skier%20Erik%20Guay%20announces%20retirement,-Erik%20Guay%20ofandtext=LAKE%20LOUISE%2C%20Alta.,Saturday's%20season%2Dopening%20men's%20downhill (accessed April 18, 2019).

Tamir, M., and Ford, B. Q. (2009). Choosing to be afraid: preferences for fear as a function of goal pursuit. *Emotion* 9, 488–497. doi: 10.1037/a0015882

Tracy, S. J. (2010). Qualitative quality: eight "big-tent" criteria for excellent qualitative research. *Qual. Inq.* 16, 837–851. doi: 10.1177/1077800410383121

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Psychology

SYSTEMATIC REVIEW
published: 04 August 2021
doi: 10.3389/fpsyg.2021.708155

Effects of Sport Teaching on Students' Enjoyment and Fun: A Systematic Review and Meta-Analysis

Manuel Rodríguez Macías, Manuel Tomás Abad Robles and Francisco Javier Giménez Fuentes-Guerra*

Faculty of Education, Psychology and Sport Sciences, University of Huelva, Huelva, Spain

OPEN ACCESS

Edited by:
Beat Knechtle, Universitätsklinikum Zürich, Switzerland

Reviewed by:
Fábio Hech Dominski, University of the Region of Joinville, Brazil
Marta Montenegro-Rueda, Sevilla University, Spain

****Correspondence:***
Manuel Tomás Abad Robles
manuel.abad@dempc.uhu.es

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *11 May 2021*
Accepted: *08 July 2021*
Published: *04 August 2021*

Citation:
Rodríguez Macías M, Abad Robles MT and Giménez Fuentes-Guerra FJ (2021) Effects of Sport Teaching on Students' Enjoyment and Fun: A Systematic Review and Meta-Analysis. Front. Psychol. 12:708155. doi: 10.3389/fpsyg.2021.708155

The methodology used in sport teaching influences not only the students' technical and tactical learning, but also psychological and social dimensions such as enjoyment. We aimed to analyze the effects of interventions using conventional and non-conventional sport teaching methodology on students' enjoyment/fun, through a systematic review and meta-analysis. The search was carried out following the PRISMA Statement in the databases of Web of Science, PubMed, Scopus, SportDiscus, Eric and PsycInfo. A total of 1,481 documents were obtained, with the addition of 5 more which were identified in the reference lists of the articles found in the databases. Eleven articles were considered to meet the inclusion criteria. The meta-analysis yielded a moderate effect size of 0.72, and a 95% CI from 0.48 to 0.96 in favor of non-conventional teaching methods, highlighting the model of sports education. Nevertheless, the heterogeneity of the interventions was large and the quality of the evidence, according to GRADE, was very low. In conclusion, the use of non-conventional models in sport teaching with the aim of increasing the enjoyment/fun of boys and girls is advised. These suggestions could be useful for teachers and sport coaches to increase the enjoyment/fun of their trainees during sport practice.

Keywords: physical education, sport pedagogy, sport teaching models, school sport, sport initiation

INTRODUCTION

Over the past two decades, the Attainment Goals Theory (Nicholls, 1989) together with the Self-Determination Theory (Deci and Ryan, 2000) and Vallerand's (2001) Hierarchical Motivation Model have examined the motivational process of physical education students, highlighting that the interpersonal style of the teacher/coach may influence this process. It is known that during adolescence there is a significant decrease in the motivation and participation of boys and girls (Sallis and McKenzie, 1991). This issue is important when boys and girls learn to play a sport (sport initiation), in physical education classes. At this stage of training it is essential that boys and girls have fun practicing sports, as this will facilitate adherence (Ortega et al., 2014). Therefore, the teacher faces the difficult challenge of getting their students to enjoy and have fun in physical education.

This question is essential, since enjoyment/fun are fundamental aspects of learning (Baena-Extremera et al., 2012b). In this sense, sport can be a means of great value, as it is often seen as a facilitator of enjoyment and fun in boys and girls. On the other hand, although enjoyment/fun and motivation are closely related, they are not concepts meaning the same thing (Wiersma, 2001). In this way, Scanlan and Lewthwaite (1986) and Fairclough (2003) consider that enjoyment/fun differs from motivation and should therefore be seen as a broader and more inclusive construct. In addition, enjoyment/fun has also been associated with intrinsic motivation (e.g., feeling of affiliation with peers, positive social interactions), with extrinsic aspects (e.g., competition, social recognition of sports achievement) and with a flow state (Wiersma, 2001). Moreno et al. (2009) define enjoyment/fun as the meaning people give to the activities performed, while motivation, according to Valle et al. (1997), is what makes an individual decide to do something in order to achieve a goal he or she has set for him or herself. Enjoyment is "a positive affective response to the sport experience that reflects generalized feelings such as pleasure, liking, and fun" (Scanlan et al., 1993, p. 6). Accordingly, Harwood et al. (2008) state that the individual goals students set for themselves can affect their motivation, effort, enjoyment, and level of physical activity. Sometimes there is a tendency to differentiate between play and learning, which is why teachers may sometimes consider motivation and enjoyment/fun to be unrelated (Gros, 2009). However, as Ntoumanis (2005) believes, when individuals have fun, they tend to be intrinsically motivated and tend to attribute more importance to the subject matter and, as a consequence, they learn more. In this sense, enjoyment gives rise to a positive reaction to participation, and may enable researchers and practitioners to ensure a positive experience for young athletes (Wiersma, 2001).

Similarly, Hassinger-Das et al. (2017) consider enjoyment/fun to be a key element in engaging children, maintaining their interest, and enhancing their learning, while Baena-Extremera et al. (2012b) state that motivation, satisfaction, and fun are crucial in order to learn. Along these lines, Riera (2010) claims that the characteristics of the tasks, the functionality of the student, the dispositional factors and the information conveyed are factors influencing the student's enjoyment/fun when learning a particular sport. For this reason, Alarcón et al. (2010) consider that the tasks should be sequences in an ascending progression in difficulty, as this facilitates the learning of a certain skill, which helps to avoid frustration and boredom of students. Accordingly, Baena-Extremera et al. (2016) consider that it is essential for students to enjoy and feel satisfied with Physical Education class, since the intention to practice sport is usually related to enjoyment/fun (Moriana et al., 2006). In this vein, studies carried out by Côté (1999), and Côté and Hay (2002) reveal that enjoyment/fun is a vital determinant of long-term sport participation. In addition, research such as Cairney et al. (2012), Leptokaridou et al. (2015), and Jaakkola et al. (2017) show that higher levels of enjoyment/fun in physical education classes lead to more motivated and engaged participation, and a significant increase in regular physical activity outside of school.

Sport is often seen as an element of fun and enjoyment. However, it is common to see participants put more emphasis on winning than on developing values such as fun, which may be due to the teaching model used (Carron and Brawley, 2008). In this way, scientific literature indicates that the methodology used in the sport teaching influences not only technical and tactical learning, but also psychological and social dimensions such as enjoyment/fun (Emmanouel et al., 1992). Ortega et al. (2008) believe that teachers and coaches should try to make activities fun and avoid those which are not, while Cecchini et al. (2014) assert that enjoyment/fun is increased when teachers promote active classes where students feel that they are the protagonists. However, conventional models are characterized by the single mandate of the teacher/coach, which obstructs the autonomy of athletes and, as a consequence, generates anxiety, boredom and even undisciplined behavior (Reeve and Tseng, 2011). Conventional or traditional approaches to sports education focus on a perfect model of technical performance that boys and girls practice repeatedly and in isolation, through non-contextualized tasks different from the real game (Blomquist et al., 2001) and through direct instruction. In these approaches, boys and girls do not feel protagonists of their learning, and enjoyment/fun may decrease (García-López et al., 2012). In this sense, non-conventional approaches are based on constructivist theory where students are seen as creative, social, and active learners who build their own knowledge and identify what they need to improve during the learning process (Dyson et al., 2004). These approaches emerge as a reaction to conventional models and focus on the simultaneous development of technique, tactical knowledge and decision-making using real game-like situations, and through problem-solving, e.g., Teaching Games for Understanding (TGfU), Sport Education Model (SE), and Cooperative Teaching. In addition, these pedagogical models promote opportunities for both boys and girls to solve problems, make decisions and demonstrate leadership (Metzler, 2011). Thus, Mouratidis et al. (2011) state that in Physical Education classes there are differences in terms of student satisfaction and enjoyment/fun depending on the way in which the teacher approaches the content. Following this line, the results obtained by Burgueño et al. (2016), reveal that the enjoyment/fun of the group receiving Physical Education classes through a non-conventional model increased, while it decreased in those who received traditional teaching. It seems advisable to use non-conventional models in sport teaching with the aim of increasing the enjoyment of students (Batez et al., 2021). Other studies have reported that the reduction of sport practice during free time by students may be related to the use of traditional teaching methodology, because teaching situations are presented in a decontextualised way (Crance et al., 2013), which may generate boredom in boys and girls, and may be far from their motivations (García-López et al., 2012). Likewise, Reeve et al. (2014) conclude that young people increase their enjoyment/fun during sports practice and that non-conventional models need to be implemented, as they allow students to have the opportunity to make decisions within the teaching-learning process and to be able to choose the tasks which best suit their interests.

As far as we are aware, only one systematic review has been carried out (Dudley et al., 2011) related to the subject matter of this study. This research analyses the published literature on the effectiveness of physical education in promoting physical activity participation (19 studies), motor skills (four studies), as well as the enjoyment/fun of physical activity (seven studies) in children and adolescents. Of the studies analyzed in this research, six were developed in Secondary Education and one in Primary Education. Only six studies provided the prescribed plan followed by teachers: two studies developed a curriculum negotiated with study participants; two studies used one or more teaching styles of Mosston and Ashworth (1986) in the intervention, and two other studies adopted approaches based on direct or explicit teaching or a direct instruction model. Nonetheless, this study did not focus on the analysis of interventions related to the sport teaching and their effects on participants' enjoyment/fun. Furthermore, the authors did not perform a quantitative analysis of the effects of the interventions. The main finding of this study was that its authors conclude their study by highlighting the lack of quality evaluations which did not obtain accurate conclusions on the effectiveness of interventions aimed at improving students' enjoyment/fun in physical education classes using different types of pedagogical models (Dudley et al., 2011). Thus, this systematic review and meta-analysis focuses on answering research questions and analyzing in detail the available evidence (studies that have answered these research questions) (Fernandez-Chinguel et al., 2019) on the use of different sport teaching methodologies and the effects on enjoyment/fun, synthesizing the results found in these researches. In this way, it is intended to answer research questions, and serve as a basis for making decisions based on evidence. No-conventional methodologies have demonstrated their potential for achieving multiple psychological benefits, technical-tactical learning, and enjoyment of physical activity (Chu and Zhang, 2018). In addition, unconventional methodologies are associated with higher levels of confidence and fun during practice (Braithwaite et al., 2011). The study carried out can be very useful when planning physical education classes or training sessions in order to find methodologies for sports teaching that boys and girls can have fun with, and increase participation and learning in sports. Another application of the study is related to the promotion of fair play in sports practice and the use of teaching models, since high levels of enjoyment/fun are related to a high level of fair play (Cecchini et al., 2007). In addition, this research may serve to underline the importance of the methodological intervention of the teacher in creating an environment in which children can perceive the practice of sport as fun, in order to encourage them to continue their practice even outside the school setting (Coppola et al., 2020). For this reason, the questions raised in this review and meta-analysis are the following: 1. Are effective those interventions aimed at developing young people's enjoyment/fun during sport practice when using non-conventional methodologies? 2. What are the characteristics of the interventions promoting to a greater extent the development of enjoyment/fun? In this sense, the aim of this study was to analyze the effects of interventions using conventional and non-conventional sport teaching methodology on students' enjoyment/fun, through a systematic review and meta-analysis.

METHOD

To perform this review and meta-analysis, we followed the Preferred Reporting Items of Systematic reviews and Meta-Analyses (PRISMA) Statement and the practical guide for systematic reviews (Urrútia and Bonfill, 2010; Moher et al., 2015; Page et al., 2021).

Eligibility Criteria

The inclusion criteria applied in this study were as follows: (a) manuscripts had to be available in full text; (b) papers had to have been published between 2000 and 2020; (c) studies had to have an intervention programme with a control group and an experimental group; (d) interventions could be in any sport; (e) the setting of the interventions should be related to physical education classes or extra-curricular sports; (f) research had to include a pre-test and a post-test; (g) manuscripts had to be in English, Portuguese or Spanish; (h) articles could not be systematic reviews or reviews of the literature; and (i) they had to show mean and standard deviation in the results obtained in the pre-test and post-test, both in the control group and in the experimental group. The exclusion criteria were: (a) studies not related to sports education using a conventional or non-conventional methodology in an educational or educational setting; (b) research that does not compare the use of a conventional methodology with an unconventional methodology for sports education; (c) studies that do not include results related to enjoyment or fun; and (d) unpublished writings between 2000 and 2020.

Papers meeting all inclusion criteria were incorporated into the systematic review. Additionally, other manuscripts were added as they were found after analysis of the references of the papers obtained from the search. In order to reduce selection bias, each study was reviewed independently by two authors, who mutually determined whether or not the manuscripts met the inclusion criteria. In case of discrepancy, this was resolved by the third investigator.

Search Strategy

The systematic search of the literature was conducted following the protocol suggested by the PRISMA guidelines (Page et al., 2021). The search was undertaken between 24 February and 30 May 2021 in the following databases: Web of Science; Scopus; Sportdiscus; Pubmed; Eric and Psycinfo. In the search process, four distinct blocks were defined to ensure that the studies shown were as closely related as possible to the subject matter of this systematic review. The search blocks were as follows: (a) teaching games OR teaching sports OR sport pedagogy; (b) sports training OR physical education; (c) fun OR enjoyment OR diversion OR entertainment OR satisfaction; (d) intervention OR experimental OR quasi-experimental OR randomized controlled trial. As an example, for the SportDiscus database the search phrase was: (teaching games OR teaching sports OR sport pedagogy) AND (sports training OR physical education) AND (fun OR enjoyment OR diversion OR entertainment OR satisfaction) AND (intervention OR experimental OR quasi-experimental OR randomized controlled trial). This search phrase was entered only in English. For the development of the search phrase, the thematic blocks were first established. Then, after searching the selected databases and articles related to the topic of study, the terms were added in each thematic block, as well as their synonyms and related terms.

Study Selection and Data Collection Process

Once the search was completed, an analysis of both the title and the abstract was run in order to find those papers most directly connected to the subject matter and to eliminate or exclude those which did not meet the inclusion criteria. After the screening process, the papers were selected for subsequent data collection. The number of papers meeting all the inclusion criteria was 11. However, it is worth mentioning that the study by Cecchini et al. (2007) considered two experimental groups.

Risk of Bias Assessment

To assess the risk of bias, the Physiotherapy Evidence Database (PEDro) scale (Maher et al., 2003) was used. Its main objective is to analyse the quality of interventions in different studies, mainly in randomized controlled trials. On the other hand, the GRADE (Grading of Recommendations Assessment, Development, and Evaluation) approach (Balshem et al., 2011) was used to assess the quality of evidence. This approach features a four-level scale ("very low," "low," "moderate" and "high"). The quality of evidence for a study is downgraded when there is poor applicability of the evidence, inconsistency or inaccuracy, or publication bias.

Data Collection

Considering the PRISMA statement, information regarding participants, comparisons, intervention, study design and outcomes (PICOS, Urrútia and Bonfill, 2010) was included (Moher et al., 2009). The studies were reviewed independently by two authors of this research. In case of doubt, this was resolved by the other investigator.

Statistical Analysis

In the meta-analysis carried out, a random-effects model was used to measure the effect of interventions on enjoyment during sport. The effect size was calculated using means and standard deviations before and after the intervention applied to participants (Morris and DeShon, 2002). For the meta-analysis, the magnitude of Cohen's d was specified as follows: (a) "large" for values above 0.8, (b) "moderate" for scores between 0.5 and 0.8 and (c) "small" for values between 0 and 0.5. Heterogeneity was assessed by calculating the following statistics: (a) Tau^2, for the calculation of between-study variance, (b) Chi^2 and (c) I^2, which is a transformation of the H-statistic, used to determine the percentage of variation caused by heterogeneity (Higgins and Thompson, 2002; Higgins et al., 2003). The most common classification of I^2 considers values above 50% as high heterogeneity, values between 25 and 50% as moderate and values below 25% as small (Higgins and Thompson, 2002). The Review Manager 5.4 tool was used to perform all analyses (Nordic Cochrane Centre the Cochrane Collaboration, 2020).

RESULTS

Study Selection

After searching the databases, a total of 1,481 documents were obtained, with the addition of five more which were identified in the reference lists of the articles found in the databases. Once the duplicates (96) were removed, a total of 1,385 articles remained, out of which 1,379 were excluded after applying the inclusion/exclusion criteria. Following this process, in the end, 11 articles were included in this systematic review (see **Figure 1**). However, some studies that might appear to meet the inclusion criteria were excluded. In this sense, the research of Myers et al. (2019) was not included because it did not directly relate to the subject under study, while the study by Yu et al. (2018) was discarded as a systematic review. Two reviewers independently analyzed the studies in the selection process, and inter-observer agreement was calculated, yielding a reliability of 97.9% (Thomas and Nelson, 2007).

Risk of Bias

Table 1 shows the results of the risk of bias of those studies which have been included in this study. Moreover, it should be noted that, for the risk of bias assessment, and for the quality of evidence assessment, the studies were reviewed independently by two authors of this research. In case of doubt, this was resolved by the other investigator.

Table 1 shows the risk of bias of the 11 articles included in the meta-analysis according to the PEDro Scale. The total study scores were equal across the eight manuscripts (seven points). In terms of quality of evidence, the GRADE guidelines were followed. The studies were not randomized clinical trials, so the rating started in low quality. Regarding the risk of bias of the results, it was not considered to lower the grade because much of the information came from studies with low risk of bias. However, the quality of evidence was downgraded on one occasion due to a high degree of heterogeneity ($Tau^2 = 0.13$; $Chi^2 = 76.27$, df = 11; $p < 0.00001$; $I^2 = 86\%$). Regarding indirectness, the rating was not lowered, since the evidence of the meta-analysis performed answered the questions of the review. As for the imprecision, since a sufficient number of people were included ($n = 938$), and since the confidence interval was not large (95% CI from 0.48 to 0.96), it was decided not to lower the score. Finally, no publication bias was detected, so the rating was not lowered for this reason. In addition, although the effect size was moderate (0.72), the rating was not upgraded. For this reason, the quality of evidence, according to the GRADE guidelines, was "very low," which was defined as "we have very low confidence in the estimate of the effect: the true effect is likely to be substantially different from the estimate of the effect" (Balshem et al., 2011, p. 404).

Characteristics of Studies

Table 2 outlines the characteristics of participants, duration, instrument, and protocol of the interventions, including the

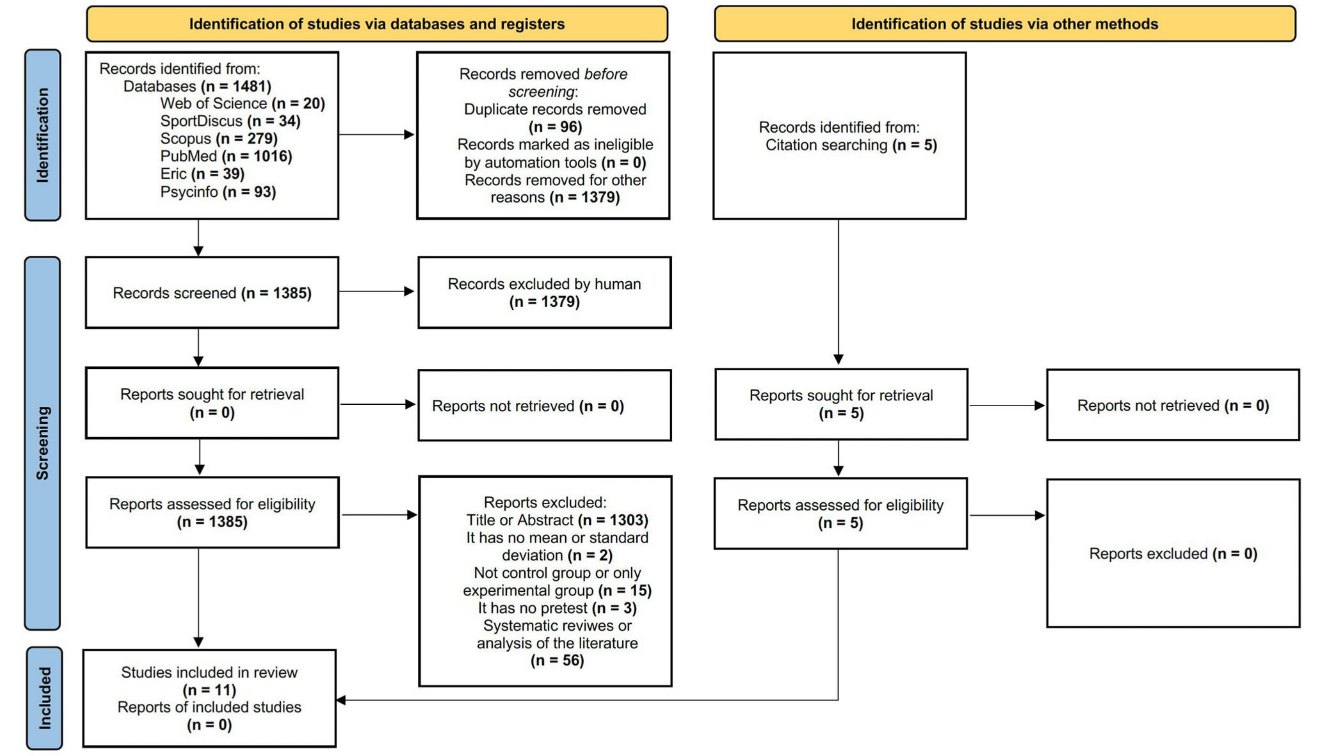


FIGURE 1 | Flowchart of the systematic review process according to the PRISMA protocols declarations.

TABLE 1 | Risk of bias according to the PEDro Scale.

Study	1	2	3	4	5	6	7	8	9	10	11	Total
Response to each item level of evidence												
Casado-Robles et al. (2020)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Cecchini et al. (2003)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Cecchini et al. (2007)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Coppola et al. (2020)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Cuevas et al. (2016)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Gil-Arias et al. (2020)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Lis-Velado and Carriedo (2019)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Spittle and Byrne (2009)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Viciana et al. (2020)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Wallhead and Ntoumanis (2004)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Wallhead et al. (2014)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7

Y, criterion fulfilled; N, criterion not fulfilled; 1, eligibility criteria were defined; 2, participants were randomly distributed into groups; 3, the assigned was concealed; 4, the groups were similar before of the intervention (at baseline); 5, all participants were blinded; 6, therapists (teachers) who conducted the intervention were blinded; 7, there was blinding of all evaluators; 8, the measures of at least one of the fundamental outcomes were attained from more than 85% of the participants initially; 9, "intention to treat" analysis was conducted on all participants who received the control condition or treatment as assigned; 10, the findings of statistical comparisons between groups were reported for at least one fundamental outcome; 11, the study gives variability and punctual measures for at least one fundamental outcome; total score: each satisfied item (except the first) adds 1 point to the total score.

sports played. In addition, **Table 3** details the objectives, the intervention programmes of each study, as well as the main findings of the research. **Table 2** describes the characteristics of the studies included in this systematic review. It should be pointed out, on the one hand, that there was a total of 1,806 participants, which were distributed in such a way that 868 subjects formed the control groups and 938 the experimental groups.

Interventions

Table 2 shows the protocol used in all studies, both in experimental and control groups. As for the control groups, most

TABLE 2 | Participants' characteristics, duration, data collection and sample selection, other variables measured, and instrument included in the systematic review and meta-analysis.

Study and Country	Study design	*N* (gender) *N* (control group and experimental group)	Age and educational level/context	Duration of the study	Data collection and sample selection	Instruments to measure enjoyment/fun	Other variables and measure instruments
Casado-Robles et al. (2020) and Granada (Spain)	Quasi-experimental	114 NR* NR*. Only 99 participated Control G. (44) Experimental G. (55)	M = 14.0 SD = 1.1 2nd and 4th year of Secondary Education[1]	6 weeks 12 sessions 2 sessions/week 1 h/session	Participants completed pre-test measures and then participated in their classes (SE and traditional teaching). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Multidimensional Sportspersonship Questionnaire (CMD) by Iturbide-Luquin and Elosua-Oliden (2017) This questionnaire consists of 21 items divided into five dimensions: (a) Enjoyment; (b) Respect; (c) Commitment; (d); (e) Participation. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly disagree" to 10 "Strongly agree"	Anthropometry. They were recorded following the International Standards for Anthropometric Assessment (Stewart et al., 2011) Perceived habitual physical activity. The perceived habitual physical activity of the participants was assessed using the PACE (Physician-based Assessment and Counseling for Exercise) questionnaire, in its version adapted and validated to the Spanish context for adolescents by Martínez-Gómez et al. (2009) Intention to be physically active. Participants' intention to be physically active was assessed using the Measure of Intention to be Physically Active (MIFA) questionnaire, in its version adapted and validated to the Spanish context by Moreno et al. (2007) Objective levels of physical activity and sedentary behavior. Levels of habitual physical activity and sedentary behavior were assessed objectively using a GT3X accelerometer (ActiGraph, LLC, Pensacola, FL, USA)
Cecchini et al. (2003) and North of Spain	Quasi-experimental	142 (73 women) (69 men) Control G. (70) Experimental G. (72)	M = 12.5 NR* 1st year of Secondary Education	10 sessions 1 h/session	Participants completed the pre-test measures and then participated in their classes (SE and traditional teaching). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Fair Play Attitudes Scale (Cruz et al., 1996) This questionnaire consists of 23 items divided into three dimensions: (a) Hard play; (b) Victory and (c) Fun. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly disagree" to 5 "Strongly agree"	Self-control. It was measured through the Child and Adolescent Self-Control Questionnaire (CACIA) (Capafons and Silva, 1998).

(Continued)

TABLE 2 | Continued

Study and Country	Study design	*N* (gender) *N* (control group and experimental group)	Age and educational level/context	Duration of the study	Data collection and sample selection	Instruments to measure enjoyment/fun	Other variables and measure instruments
Cecchini et al. (2007) and Asturias (Spain)	Quasi-experimental	186 (94 women) (92 men) Control G. (61) Experimental G.A (63) Experimental G.B (62)	M = 13.6 SD = 0.30 2nd year of Secondary Education	2 months	Participants completed the pre-test measures and then participated in their classes (Hellison Programme and traditional teaching). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Fair Play Attitudes Scale (Cruz et al., 1996) This questionnaire consists of 23 items divided into three dimensions: (a) Hard play; (b) Victory and (c) Fun. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly disagree" to 5 "Strongly agree"	Self-control. It was measured through the Child and Adolescent Self-Control Questionnaire (CACIA) (Capafons and Silva, 1998).
Coppola et al. (2020) and Italy	Quasi-experimental	66 (35 women)(31 men) Control G. (32) Experimental G. (34)	M = 8.6 SD = 0.4 4th year of Primary Education	22 weeks 1 session/week 1 h/session	Participants completed pre-test measures and then participated in their classes (Tactical Model and traditional teaching). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Physical Activity Enjoyment Scale (PACES) questionnaire (Carraro et al., 2008) This questionnaire consists of 16 items. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly Disagree" to 5 "Strongly Agree"	This study only measured enjoyment
Cuevas et al. (2016) and Spain	Quasi-experimental	86 (49 women) (37 men) Control G. (43) Experimental G. (43)	M = 15.65 SD = 0.78 4th year of Secondary Education	19 sessions 55 min/twice a week	Participants completed the pre-test measures and then participated in their classes (DE and traditional teaching). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Spanish version (Balaguer et al., 1997) of the original Intrinsic Satisfaction Classroom Scale (ISC) (Duda and Nicholls, 1992) This questionnaire consists of 16 items divided into two dimensions: (a) Satisfaction/Enjoyment; (b) Boredom. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly disagree" to 5 "Strongly agree"	Motivational regulation. It was measured through the Questionnaire for the Evaluation of Motivation in Physical Education (CMEF) (Sánchez-Oliva et al., 2012) Intention to be physically active. It was measured through the Intention to Be Physically Active Scale (IPAS) (Hein et al., 2004), but the Spanish version of the Spanish version was used (Moreno et al., 2007)

(Continued)

TABLE 2 | Continued

Study and Country	Study design	*N* (gender) *N* (control group and experimental group)	Age and educational level/context	Duration of the study	Data collection and sample selection	Instruments to measure enjoyment/fun	Other variables and measure instruments
Gil-Arias et al. (2020) and Southeast Spain	Quasi-experimental	292 (140 women)(152 men) Control G. (144) Experimental G. (148)	M = 10.41 SD = 0.49 5th year of Primary Education	8 weeks 16 sessions 50 min/twice a week	Participants completed pre-test measures and then participated in their classes (Hybrid TGfU/ED and direct instruction). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Spanish version (Sicilia et al., 2014) of Physical Activity Class Satisfaction Questionnaire (Cunningham, 2007) This questionnaire consists of 45 items divided into nine dimensions, although in this study only (a) Fun/Enjoyment; (b) Interaction with others; (c) Experiences of mastery; (d) Experience of fun were evaluated. All of them are evaluated with an 8-point Likert scale ranging from 1 "Strongly Disagree" to 8 "Strongly Agree"	Autonomy support. The Spanish version (Conde et al., 2010) of the Autonomy Support Strategies Questionnaire of coaching strategies (Conroy and Coatsworth, 2007) Satisfaction of Basic Psychological Needs (BPN) To assess satisfaction with BPN, the Spanish adaptation of the BPN in exercise scale (Vlachopoulos and Michailidou, 2006), specific to the context of physical education, was used (Moreno-Murcia et al., 2008, 2009) Autonomous motivation. The Spanish version (Ferriz et al., 2015) of the Perceived Locus of Causality Questionnaire was used to provide composite scores for autonomous motivation (Goudas et al., 1994) Friendship goals. The Spanish adaptation (Méndez-Giménez et al., 2014) of the friendship relationship goals questionnaire (Elliot et al., 2006) was used
Lis-Velado and Carriedo (2019) and North of Spain	Quasi-experimental	92 (42 women)(50 men) Control G. (45) Experimental G. (47)	M = 10.38 SD = 0.55 5th year of Primary Education	3 sessions 60 min/session	Participants completed the pre-test measures and then participated in their classes (Brave League and traditional competitive system). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Fair Play Attitudes Scale (Cruz et al., 1996) This questionnaire consists of 23 items divided into three dimensions: (a) Hard play; (b) Victory and (c) Fun. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly disagree" to 5 "Strongly agree"	Goal orientations. The Spanish version (Cervelló et al., 1999) of the Perception of Success Questionnaire (POSQ) (Roberts and Balagué, 1991; Roberts et al., 1998) was used Pressure-strain and effort. Two of the four subscales of the Intrinsic Motivation Questionnaire (IMI) by McAuley et al. (1989), which was translated and validated in Spanish by Escartí and Gutiérrez (2001), were used to measure the pressure-strain and effort perceived by the students

(Continued)

TABLE 2 | Continued

Study and Country	Study design	*N* (gender) *N* (control group and experimental group)	Age and educational level/context	Duration of the study	Data collection and sample selection	Instruments to measure enjoyment/fun	Other variables and measure instruments
Spittle and Byrne (2009) NR*	Quasi-experimental	115 (18 women) (97 men) Control G. (74) Experimental G. (41)	NR* NR* 2nd year of Secondary Education	10 weeks 100 min/weeks	Participants completed the pre-test measures and then participated in their classes (SE and traditional teaching). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Intrinsic Motivation Inventory (IMI) (Ryan, 1982), reformulated for use in sport settings by McAuley et al. (1989) This questionnaire consists of 18 items divided into four dimensions: (a) Enjoyment/Interest; (b); Effort/Importance; (c) Perceived Competence; Pressure/Strain. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly disagree" to 5 "Strongly agree"	Goal orientation. Goal orientations were assessed using the Task and Ego Orientation in Sport Questionnaire (TEOSQ). (Duda and Nicholls, 1992) Motivational climate. Perceived motivational climate was measured with the Perceived Motivational Climate in Sport Questionnaire (PMCSQ). (Walling et al., 1993)
Viciana et al. (2020) and Ceuta (Spain)	Quasi-experimental	123 (60 women) (63 men) Only 109 participated Control G. (42) Experimental G. (67)	NR* NR* 3rd year of Secondary Education	12 sessions	Participants completed the pre-test measures and then participated in their classes (SE and traditional teaching). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Spanish version adapted to physical education (Baena-Extremera et al., 2012a) of the Sport Satisfaction Instrument This questionnaire consists of 8 items divided into two dimensions: (a) Satisfaction/Fun; (b) Boredom. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly disagree" to 5 "Strongly agree"	Motivation toward Physical Education. The Spanish version of the Perceived Locus of Causality (Moreno et al., 2009) was used. Perceived physical fitness, sport competence and coordination. For these physical self-concept subscales, two questionnaires were used (a) the Spanish version of the Physical Self-perception (Moreno and Cervelló, 2005); (b) the Spanish version of the Physical Self-description (Tomás, 1998) Effort and self-improvement. The effort and improvement subscale belonging to the Spanish version of the Perceived Motivational Climate in Sport Questionnaire (PMCSQ-2). (González-Cutre et al., 2008) Relationship. The Spanish version of the Cuestionario Basic Psychological Needs in Exercise (BPNES) (Sánchez and Núñez, 2007)

(Continued)

TABLE 2 | Continued

Study and Country	Study design	*N* (gender) *N* (control group and experimental group)	Age and educational level/context	Duration of the study	Data collection and sample selection	Instruments to measure enjoyment/fun	Other variables and measure instruments
							Cooperative learning and important role. The cooperative learning and important role subscales belonging to the Spanish version of the PMCSQ-2 (González-Cutre et al., 2008) Classroom climate. Classroom climate was measured with the Spanish version of the Classroom Environment Inventory (Marcelo, 1992) Sportsmanship. The Spanish version of the Multidimensional Scale of Sport Orientations (MSOS) by Martín-Albo et al. (2006) Intention to be physically active questionnaire. The Spanish version of the intention to be physically active (Moreno et al., 2007) Autonomy support. Spanish version of the BPN (Sánchez and Núñez, 2007)
Wallhead and Ntoumanis (2004) and North of England	Quasi-experimental	51 NR* NR* Control G. (26) Experimental G. (25)	M = 14.3 SD = 0.48 2nd year of Secondary Education	8 sessions 1 h/sesssion	Participants completed pre-test measures and then participated in their classes (SE and traditional teaching). Post-test measures were completed in the last class of each methodology. Cluster Randomized	Intrinsic Motivation Inventory (IMI) (Ryan, 1982), reformulated for use in sport settings by McAuley et al. (1989) This questionnaire consists of 18 items divided into four dimensions: (a) Enjoyment/Interest; (b); Effort/Importance; (c) Perceived Competence and (d) Pressure/Strain. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly Disagree" to 5 "Strongly Agree"	Goal orientation. Goal orientations were assessed using the Task and Ego Orientation in Sport Questionnaire (TEOSQ). (Duda and Nicholls 1992) Perceived autonomy. Students' perceived autonomy was assessed using a 20-item questionnaire adapted to physical education by Goudas et al. (1994). The items were taken from the Academic Self-Regulation Questionnaire (ASRQ) (Ryan and Connell, 1989) and the Academic Motivation Scale (Vallerand et al., 1992) Perceptions of motivational climate. These were assessed with the Learning and Performance Orientation in Physical Education Classes Questionnaire (LAPOPECQ). (Papaioannou, 1995)

(Continued)

TABLE 2 | Continued

Study and Country	Study design	*N* (gender) *N* (control group and experimental group)	Age and educational level/context	Duration of the study	Data collection and sample selection	Instruments to measure enjoyment/fun	Other variables and measure instruments
Wallhead et al. (2014) and Midwestern (United States)	Quasi-experimental	568 (310 women) (258 men) Control G. (287) Experimental G. (281)	M = 14.75 SD = 0.48 3rd year of Secondary Education	9 months 2 session/week 45 min/sesssion	It is possible that different types of activities (e.g., cooperative games vs. team sports vs. individual sports) may have caused temporary fluctuations in student motivation. Cluster Randomized	Intrinsic Motivation Inventory (IMI) (Ryan, 1982), reformulated for use in sport settings by McAuley et al. (1989) This questionnaire consists of 18 items divided into four dimensions: (a) Enjoyment/Interest; (b); Effort/Importance; (c) Perceived Competence and (d) Pressure/Strain. All of them are evaluated with a 5-point Likert scale ranging from 1 "Strongly disagree" to 5 "Strongly agree"	Type of autonomous motivation. Autonomous motivation type was assessed using the Perceived Locus of Causality Questionnaire presented by Goudas et al. (1994) NPB. The NPB Scale adapted to physical education (Ntoumanis, 2005) Intention to be physically active. The Physical Activity Intention Scale followed the model of (Fishbein and Ajzen, 2010).

NR, not reported.*
[1]According to the Spanish educational system.

of the studies involved traditional teaching (Cecchini et al., 2003, 2007; Wallhead and Ntoumanis, 2004; Spittle and Byrne, 2009; Cuevas et al., 2016: Coppola et al., 2020; Viciana et al., 2020). The control groups of Casado-Robles et al. (2020) and Gil-Arias et al. (2020), received the lessons through direct instruction, while the control group of Lis-Velado and Carriedo's (2019) study conducted a traditional competitive system. Finally, the study by Wallhead et al. (2014) received the lessons through multiactivity program.

Concerning the experimental groups, both in the study by Cuevas et al. (2016), and in those by Wallhead and Ntoumanis (2004), Spittle and Byrne (2009), Wallhead et al. (2014), Casado-Robles et al. (2020), and Viciana et al. (2020), the classes were taught using the SE. On the contrary, the studies by Cecchini et al. (2003) and Cecchini et al. (2007) worked on the basis of the Hellison Programme 1995. The experimental groups of the Lis-Velado and Carriedo (2019) and Coppola et al. (2020) studies were taught through a tactical game model and Brave League, respectively. Finally, the experimental group in the Gil-Arias et al. (2020) research was taught using a hybrid model between the TGfU and the SE. **Table 3** shows the objectives, intervention programmes and main results of the articles included in this systematic review.

Outcomes Measure

Figure 2 depicts that 11 studies obtained improvements in enjoyment during the development of sport practice through non-conventional methods. The differences were significant in five studies (Cecchini et al., 2003, 2007; Wallhead and Ntoumanis, 2004; Spittle and Byrne, 2009; Wallhead et al., 2014; Cuevas et al., 2016; Gil-Arias et al., 2020; Viciana et al., 2020). In additionno significant differences were observed in the studies conducted by Lis-Velado and Carriedo (2019) and Coppola et al. (2020). Finally, no improvements in favor of the experimental group, i.e., the non-conventional model, were observed in the study performed by Casado-Robles et al. (2020). The total effect size was 0.72, with a 95% CI from 0.48 to 0.96, which, following the proposed classification, was a moderate effect size. However, the level of heterogeneity was large: $Tau^2 = 0.13$; $Chi^2 = 76.27$, df $= 11$ ($p < 0.00001$); $I^2 = 86\%$; test for total effect: $Z = 5.93$ ($p < 0.00001$).

DISCUSSION

The aim of this study was to analyze the effects of interventions using conventional and non-conventional sport teaching methodology on students' enjoyment/fun, through a systematic review and meta-analysis. The main result was that, in general, the interventions implemented in the studies analyzed showed significant improvements. Thus, this significant increase can be considered moderate, according to the overall effect size (0.72, with a 95% CI from 0.48 to 0.96 with p-value < 0.00001). This is consistent with previous studies that reported that the use of no-conventional methodologies promoted enjoyment/ fun during sports practice in boys and girls (López and Castejón, 2005; MacPhail et al., 2008; Perlman, 2010). However, due to the high heterogeneity ($I^2 = 86\%$) and the low quality of the evidence,

TABLE 3 | Objectives, intervention programme, main results, conclusions, and limitations of the research included in the systematic review and meta-analysis.

References	Objectives and hypotheses	Intervention programme		Main Results	Conclusions	Limitations
		Control Group	**Experimental Group**			
Casado-Robles et al. (2020)	To measure the effect of a teaching unit of the Sport Education Model in physical education on sportspersonship and on the levels of regular physical activity Hypothesis: NR*	The students belonging to the control group played basketball during Physical Education classes following a traditional teaching method.	The students in the experimental group played basketball during Physical Education classes following the SE.	The Sport Education Model programme improved the students' sportspersonship dimension. However, there were no significant differences on the other dimensions of sportspersonship or on the students' regular physical activity levels.	A 12-session SE didactic unit increased students' desire and willingness to participate in sport competitions by applying maximum effort. However, the programme does not have a greater effect compared to the traditional model on the other dimensions of sportsmanship, nor on levels of habitual physical activity and intention to be physically active. For this reason, the effect of the programme should be tested in other contexts (e.g., with longer programme duration and/or different content)	Duration of programme (12 sessions) High number of excluded participants and, consequently, low final sample size (45 participants) Sample from a single school
Cecchini et al. (2003)	To assess the impact of Hellison's (1995) Intervention Programme for Developing Personal and Social Responsibility on fair play behaviors and on self-control Hypothesis: In a relatively short time, the implementation of this programme would generate positive changes in the opinions and behaviors related to fair-play in sport, as well as in personal self-control in other domains outside sport	The boys and girls in the control group played indoor football during physical education classes following a traditional teaching method.	The boys and girls in the experimental group practiced indoor football during Physical Education classes following the Hellison intervention programme, which is structured in five levels of responsibility. (a) respecting the rights and feelings of others; (b) being motivated; (c) autonomy; (d) helping others; (e) applying these responsibilities to other domains outside sport.	Significant improvements were observed in personal feedback, reward delay, criterial self-control, process self-control, fun-related opinions, and sporting behaviors. Decreases were observed in variables related to rough play, contact fouls and unsporting behaviors. Finally, no significant changes were found in the control group.	Physical activities can be, when properly addressed, a vehicle for effecting changes in social and moral development in children and adolescents. In addition, it is possible to successfully implement a programme of 'personal responsibility and social responsibility' in physical education classes, providing a useful tool for moral development and moral development through sport and physical activity	NR*
Cecchini et al. (2007)	To assess the impact of Hellison's (1995) Intervention Programme for Developing Personal and Social Responsibility on fair play behaviors and on self-control Hypothesis: Level 5 of Hellison's (1995) programme is essential for the transfer to take place	The control group students played five-a-side football during Physical Education following a Traditional teaching method	The students of the experimental groups A and B practiced indoor football following the Hellison intervention programme, which is structured in five levels of responsibility, which were worked on by group A, while group B only worked on the first four. (a) respecting the rights and feelings of others; (b) being motivated; (c) autonomy; (d) helping others; (e) applying these responsibilities to other domains.	In the experimental groups A and B, significant improvements were observed in personal feedback, reward delay, criterial self-control, process self-control, fun-related opinions, and sporting behaviors. Decreases were observed in variables related to rough play, contact fouls and unsporting behaviors. Finally, no significant changes were found in the control group.	It is possible to successfully implement a programme of "personal responsibility and social responsibility" in physical education classes, providing a useful tool for moral development through sport and physical activity	Sample. Given that there are many factors that influence transfer, such as age, mental ability personality and motivation

(Continued)

TABLE 3 | Continued

References	Objectives and hypotheses	Intervention programme		Main Results	Conclusions	Limitations
		Control Group	**Experimental Group**			
Coppola et al. (2020)	To analyse the effects of two different teaching approaches on students' levels of enjoyment Hypothesis: NR*	The boys and girls in the control group played different sports (basketball, handball, football, and volleyball) in Physical Education classes following a Traditional teaching method.	The boys and girls in the experimental group played basketball, handball, football and volleyball during physical education classes following this approach: a tactical problem, a lesson approach and an objective.	The results obtained revealed that male participants in the experimental group did not show variations in the levels of the enjoyment scale, while female participants, although starting from a lower level, had increases in the scale scores in the post-intervention, although not statistically significant.	Recent work has shown how the TGM approach is functional both for the personal development of students and for the learning of skills that can go beyond motor-sport practice (curricular and extracurricular), also affecting enjoyment	The duration and frequency of the interventions, as it was only 1 h per week
Cuevas et al. (2016)	To analyse the impact of the Sport Education Model on self-determination, motivation, frustration of basic psychological needs, enjoyment-satisfaction, boredom in Physical Education of secondary school students Hypothesis: NR*	The students in the experimental group, during the Physical Education sessions, played volleyball following a Traditional teaching method.	Students in the experimental group played volleyball in physical education classes, following the SE.	The results showed significant improvements in different items such as enjoyment and intrinsic motivation in favor of the Experimental Group.	Through the implementation of group work, opportunities for social interaction between team members are provided; however, these opportunities may be significantly reduced by other classmates who are members of opposing teams	Sample size, sample selection method and duration of the intervention
Gil-Arias et al. (2020)	To investigate the motivational outcomes of primary school children participating in an invasion game unit through two pedagogical models: a hybrid TGfU/Sport Education unit or a Direct instructions unit Hypothesis: Boys and girls participating in the hybrid TGfU/SE unit will report higher levels of autonomy support compared to boys and girls participating in the direct instruction unit Children taught through the hybrid TGfU/SE model will report higher scores on all post-intervention variables compared to pre-intervention children participating in the direct instruction model	The boys and girls belonging to the control group practiced different invasion sports in Physical Education following a traditional teaching method.	The boys and girls in the experimental group played different invasion sports through hybrid TGfU/ SE sessions during Physical Education lessons.	Significant differences in student motivation were observed for both boys and girls who participated in the TGfU/SE hybrid unit.	A hybrid TGfU/SE unit can be implemented in a physical education context as it can lead to significant improvements in students' self-determined motivation when compared to a direct instruction unit	Only the effects of a hybrid TGfU/SE season were examined

(Continued)

TABLE 3 | Continued

References	Objectives and hypotheses	Intervention programme		Main Results	Conclusions	Limitations
		Control Group	Experimental Group			
Lis-Velado and Carriedo (2019)	To analyse the impact of the innovative Brave League on goal orientations, fair play, effort, and pressure-stress. Hypothesis: NR*	The students belonging to the control group played indoor football during the physical education sessions following a traditional competitive system (points, ranking, etc.).	The students in the experimental group practiced indoor football during Physical Education following a competitive system based on the innovative format of the Brave League, where fair play behaviors determine the order in the ranking.	The results attained suggest that competitive formats could have a positive impact on task orientation, enjoyment, and effort during sport competitions.	The proximity in time between the pre and post measurement The Brave League format can produce changes in a relatively short period of time in the task orientation and effort of the participants without altering the perceived enjoyment during the competition	The number of participants The short time spent on the intervention in each of the groups
Spittle and Byrne (2009)	To investigate the influence of the SE on student motivation (intrinsic/extrinsic motivation, goal orientations and perceived motivational climate) in secondary school Physical Education Hypothesis: Enjoyment, perceived competence, effort, task orientation and mastery-oriented motivational climate would increase significantly. In addition, pressure/strain, ego-orientation, and performance-oriented climate would decrease due to SE. A task climate would be related to increased intrinsic motivation, and a performance climate would be related to ego-goal orientation and decreased intrinsic motivation	The students in the control group played soccer and field hockey during the physical education sessions, following a traditional teaching method	Students in the experimental group, in physical education classes, played soccer, hockey and "code football" a combination of Australian Rules Football, Gaelic football and played soccer, field hockey and "code soccer" (combination of Australian Rules Football, Gaelic soccer and touch soccer) following the Sports Education model	There was a significant difference between conditions on changes in perceived competence, task orientation and mastery climate. There were no significant differences in enjoyment/fun, effort, and pressure.	SE was more successful in maintaining high levels of intrinsic motivation, task orientation and climate of mastery than the traditional condition	Existence of several confounding variables that were not controlled for or measured; consequently, it is difficult to conclude a causal relationship between the independent variable and the dependent variables

(Continued)

TABLE 3 | Continued

References	Objectives and hypotheses	Intervention programme		Main Results	Conclusions	Limitations
		Control Group	Experimental Group			
Viciana et al. (2020)	To analyse the effect of a physical education-based and Sport education programme on personal and interpersonal variables, on the social environment and on the predisposition to acquire positive habits and autonomy Hypothesis: NR*	The boys and girls belonging to the control group practiced volleyball following a Traditional teaching method during Physical Education classes, combining tasks with reduced game situations and Direct instructions methodologies.	The boys and girls in the experimental group played volleyball during the P.E. sessions following the SE based on games and competitions of volleyball game situations.	Participants in the Experimental Group had a statistically significant increase in scores on the following dimensions: personal (self-determined motivation toward physical education, satisfaction/enjoyment toward sport and physical self-concept); interpersonal (relationship with others, cooperative learning, and important role within the group); social (Physical Education classroom environment and sportspersonship); and autonomy and habit acquisition (support for autonomy and intention to be physically active) when compared to the Control Group.	It is very useful to design effective programmes that allow for positive results in terms of interpersonal, social and habit acquisition, fun, motivation, and autonomy to improve pupils' citizenship education	Issues beyond the control of the researchers Lack of personal resources
Wallhead and Ntoumanis (2004)	To analyze the influence of a SE intervention program on students' motivational responses in a high school physical education setting Hypothesis: Students in the SE group would report a greater increase in enjoyment, perceived effort, and perceived competence than those in the traditional curriculum group. Changes in SE students' perceptions would significantly predict the intervention dependent variables of students' enjoyment, effort and competence	The boys and girls in the control group, during the Physical Education sessions, played basketball following traditional teaching	The boys and girls in the experimental group, in physical education classes, played basketball following the SE	The SE increases the perception of a climate of task involvement and perceived autonomy and in doing so, increase motivation and enjoyment of high school students toward physical education	The SE has many structural features that have the potential to foster more adaptive motivational responses from students by creating an environment that allows for self-improvement, choice, and equity for students	One was the size and composition of the intervention sample. With only two groups of boys in its design, this study cannot be easily generalized to girls participating in the SE There is also the possibility of bias, as the researcher acted as a teacher and was aware of the aims of the study
Wallhead et al. (2014)	To examine the effect of the SE in high school on student motivation in Physical Education Hypothesis: Participants completed pre-test measures and then participated in their classes (SE and multi-activity programme). Post-test measures were completed in the last class of each methodology	The students in the control group played, during physical education sessions, volleyball, badminton, soccer, ultimate, cooperative games, handball, and basketball following a multi-activity model	Students in the experimental group, field hockey, volleyball, handball, basketball, during the physical education sessions, following SE	The results showed that the SE generates a greater enjoyment of the program in students compared to the students of the multi-activity model	SE facilitates more internalized forms of student motivation, but without the provision of an appropriately designed extra-curricular outlet, the potential may drop considerably	SE may not have used pedagogies that maximize support for full autonomy

NR, not reported.*

Study or Subgroup	No Convencional Model Mean	SD	Total	Convencional Model Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Casado-Robles et al. (2020)	−0.34	1.74	55	0.04	2.3	44	4.8%	−0.38 [−1.20, 0.44]
Cecchini et al. (2003)	1	0.65	72	0.05	0.7	70	10.2%	0.95 [0.73, 1.17]
Cecchini et al. (2007)_1	1.04	0.65	63	−0.02	0.58	61	10.2%	1.06 [0.84, 1.28]
Cecchini et al. (2007)_2	1.02	0.67	62	−0.02	0.58	61	10.2%	1.04 [0.82, 1.26]
Coppola et al. (2020)	0.14	0.56	34	−0.07	0.51	32	9.9%	0.21 [−0.05, 0.47]
Cuevas et al. (2016)	0.31	0.81	43	−0.24	0.89	43	8.9%	0.55 [0.19, 0.91]
Gil-Arias et al. (2020)	0.34	0.82	148	−0.37	0.75	144	10.5%	0.71 [0.53, 0.89]
Lis-Velado and Carriedo (2019)	−0.09	0.7	47	−0.23	0.78	45	9.4%	0.14 [−0.16, 0.44]
Spittle and Byrne (2009)	2.05	4.4	41	−1.4	4.13	74	1.8%	3.45 [1.81, 5.09]
Viciana et al. (2020)	0.92	1.17	67	−0.11	1.12	42	8.1%	1.03 [0.59, 1.47]
Wallhead and Ntoumanis (2004)	0.5	1.83	281	0.03	1.69	287	9.6%	0.47 [0.18, 0.76]
Wallhead et al. (2014)	1.09	1.21	25	−0.12	0.93	26	6.6%	1.21 [0.62, 1.80]
Total (95% CI)			**938**			**929**	**100.0%**	**0.72 [0.48, 0.96]**

Heterogeneity: $Tau^2 = 0.13$; $Chi^2 = 76.27$, $df = 11$ ($P < 0.00001$); $I^2 = 86\%$
Test for overall effect: $Z = 5.93$ ($P < 0.00001$)

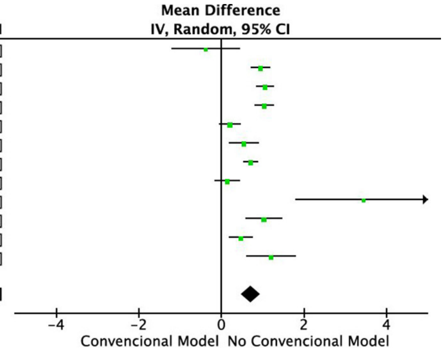


FIGURE 2 | Results of the meta-analysis of the effects of interventions on fun in sport practice.

the interpretation of the results obtained in the meta-analysis should be considered cautiously (Balshem et al., 2011), and, for that reason, any estimate of effect is very uncertain (Guyatt et al., 2008). In addition, since the interventions were administered to whole classes and not to individual students, the unit of statistical analysis should have been the class, so, for that reason, the results might be biased (Li et al., 2017). Therefore, more studies are needed on the effects of sport education on the enjoyment/fun of students.

The study by Cecchini et al. (2003) obtained a large effect size (0.95, with 95% CI from 0.73 to 1.17) in favor of the experimental group, as did the studies by Cecchini et al. (2007), which also reached a large effect size (1.06, with 95% CI from 0.84 to 1.28 and 1.04, with 95% CI from 0.82 to 1.26, respectively) (see **Figure 2**). It is worth underlining that, in these investigations, the experimental groups were taught with the Hellison Programme 1995, which emphasizes individual decision-making, group meetings and reflection, focusing the responsibility on the students, who are gradually achieving a greater degree of autonomy (Cecchini et al., 2003). This model is structured in five levels of responsibility: (a) respecting the rights and feelings of others; (b) being motivated; (c) autonomy; (d) helping others; (e) applying these responsibilities to other domains outside of sport. Similarly, both the studies by Spittle and Byrne (2009) and Wallhead et al. (2014), obtained a large effect size (3.45 with a 95% CI of 1.81–5.09 and, 1.21 with a 95% CI of 0.62–1.80, respectively). In that case, the experimental groups received their physical education classes through the SE. On the other hand, with an effect size of 1.03 and with a 95% CI from 0.59 to 1.47, in the study carried out by Viciana et al. (2020) the boys and girls in the experimental group were taught following the Game-based SE and volleyball game situations competitions, while those in the control group were taught following traditional volleyball teaching. Meanwhile, both the studies by Cuevas et al. (2016) and Gil-Arias et al. (2020), obtained a moderate effect size, where the experimental groups were delivered their physical education classes through the SE and a hybrid between TGfU and SE, respectively. Also, the study conducted by Wallhead and Ntoumanis (2004) obtained a small effect size in favor of the experimental group, who developed their physical education classes through the SE. This data is consistent with the fact that many physical education interventions using the SE (Alexander et al., 1993; Perlman, 2010). So, this model has demonstrated its potential for achieving multiple benefits, including increased enjoyment of physical activity and sport (Chu and Zhang, 2018). It seems that this increased enjoyment/fun is related to students having fun with this model because they learn sports skills as well as personal and social skills (Alexander and Luckman, 2001) and because boys and girls work in cooperative groups (Hastie, 1996). Furthermore, the study by Coppola et al. (2020) showed a small effect size in favor of the experimental group using a tactical game model, which is consistent with those obtained by Schembri et al. (2021) Similarly, the research by Lis-Velado and Carriedo (2019) showed a small effect size in favor of the experimental group, where the experimental group implemented the physical education classes through the Brave League. Finally, out of all the studies included in the systematic review and meta-analysis, only the study by Casado-Robles et al. (2020) presented results in favor of the control group.

The duration of the studies ranged from ∼3 to 22 h. These differences in the duration of the interventions seem to indicate that the benefits obtained by the experimental groups may not be due to the duration of the interventions. For this reason, regardless of the duration of the intervention, it seems advisable to use non-conventional models in sport teaching with the aim of increasing the enjoyment of students, which is in line with the findings of Batez et al. (2021).

As it has been proven, the experimental groups in the studies carried out by Wallhead and Ntoumanis (2004), Spittle and Byrne (2009), Wallhead et al. (2014), Cuevas et al. (2016), Gil-Arias et al. (2020), and Viciana et al. (2020), conducted their physical education classes using the SE, and an increase in enjoyment was observed in comparison with the control groups. Based on the data obtained, the implementation of the SE significantly promotes enjoyment/fun, with what seems to be a desirable model to increase enjoyment/fun of boys and girls during the practice of sports. In this sense, Carlson and Hastie (1997) consider that the SE can help teachers to improve students' motivation, as it encourages socialization, decision making and, in addition, favors enjoyment in competitive situations where effort levels are strongly valued. In this regard, Cecchini et al. (2014) deem important for the teacher to promote a fun atmosphere where the effort and personal progress of the student is valued, which will be reflected in the intention of the students to be physically active.

Sport is often perceived as a setting which encourages fun and enjoyment, yet it is increasingly common to observe that young people, along with their teachers/coaches, focus more on achieving victories than on instilling values such as fun in children, which may be primarily due to the teaching model used (Carron and Brawley, 2008). In the study performed by Lis-Velado and Carriedo (2019), it was noticed that the Brave League fostered more enjoyment than traditional competition. This study implemented a competitive system based on the innovative, where fair play behaviors determine the order in the ranking. It should be noted that the adoption of competition ranking systems is not based solely on match results, but, taking into account aspects of sporting behavior and fair play, can motivate students and increase enjoyment and fun (Ortega et al., 2014), since an excessive emphasis on the outcomes of competitive sports would be negatively related with enjoyment of the game (Cruz et al., 1996). Thus, Buelens and Poelmans (2004) suggest that enjoyment is connected to notions of participation and integration within a team or group. Furthermore, Kirk (2005) also suggests that the focus of young people's attention should tend to be on fun and enjoyment. In the study performed by Coppola et al. (2020) the practical task focused on the development of movements and skills related to the tactical problem of the lesson. At the end of the class, he dedicated a questioning time used to verify how the students focused on the tactical problem of each lesson and what strategies they proposed to solve it (Mitchell et al., 2013). In this sense, the tactical approach and the TGfU promote fun and enjoyment among boys and girls (López and Castejón, 2005) and are related to constructivist and situated learning theories (Kirk and MacPhail, 2002), where the student's knowledge construction takes place in games, solving problems, and reflection (Forrest, 2015).

It is also worth mentioning that several investigations such as those by Wang et al. (2002), Papaioannou et al. (2006), and García-Bengoechea et al. (2010) relate enjoyment and increased physical activity and participation. Furthermore, Barkoukis et al. (2010) report that a learning-oriented atmosphere has a direct relationship with enjoyment, while Garn and Cothran (2006) underline that enjoyment seems to be a key factor in physical education classes. Moreover, Miller et al. (2005) reinforce this idea when they consider that in Physical Education classes, enjoyment is an important element of motivation when it comes to students facing the sessions proposed by the teacher. This is important, because when students are intrinsically motivated, they show interest in an activity, they experience enjoyment and feelings of competence and control (Deci and Ryan, 1985). This issue has been highlighted in the results obtained in this meta-analysis, since in most of the studies it was found that in physical education sessions in which non-conventional methodologies were used, students showed a significant increase in enjoyment, and this could be due to the fact that boys and girls felt that they were the protagonists of the teaching-learning process (Cecchini et al., 2014), and to the fact develop a self-referenced competence or gain mastery of a task (Treasure and Roberts, 2001). In this sense, in the sports education model, the students gradually assume greater responsibility, while teachers relinquish traditional up-front direct teaching roles (Alexander and Luckman, 2001). The teacher, in this way, acts as a facilitator through a series of student-centered learning strategies (Wallhead and Ntoumanis, 2004). Yet, this was not the case when they were taught in a traditional, non-student-centered way. Continuing along these lines, in non-conventional methods a wide variety of modified games or reduced situations are posed, in which students have to analyse the situation and execute the actions (Serra et al., 2011), which generates both cognitive engagement and fun (Montero, 2017). Another aspect also considered in non-conventional methods, which promotes fun and enjoyment among boys and girls, is the contextualization of the games, i.e., that they are close to the sport they are playing (López and Castejón, 2005). In view of the above, and considering the results of this study, it seems advisable to use non-conventional methods for teaching and practicing sports in order to increase the enjoyment/fun of boys and girls, which may increase their participation and learning (Côté, 1999; Côté and Hay, 2002; Hassinger-Das et al., 2017).

This systematic review with meta-analysis has some limitations. One of them relates to the fact that the literature search was limited to three languages: Spanish, English, and Portuguese; and was limited only to articles available in full text Another limitation to consider is the high heterogeneity shown in the meta-analysis, which suggests that the interpretation of the results should be approached cautiously. Furthermore, future research could focus on the impact of the TGfU and of the SE on enjoyment, as there is a lot of research concerning the impact of these approaches on motivation, but little research on enjoyment. Another future investigation, due to the scarce studies found in this review, could be the analysis of the influence of the methodology used in sport teaching in other contexts, such as, for instance, in extracurricular sport in schools and sports clubs. Future studies could also focus on clarifying the concepts of enjoyment and fun and their relationship to aspects such as intrinsic motivation. In addition, future research should also focus on the development of more powerful tools for assessing the quality of studies, both quantitative and qualitative and with different methodological designs.

In order to answer the questions of the review presented at the beginning of the manuscript, it should be said that interventions based on non-conventional methodologies have been shown to be effective for the development of enjoyment/fun among young people. In addition, in terms of the characteristics of the interventions that led to an improvement in enjoyment/fun, the results showed that interventions based on model of sports education achieved a significant increase. The findings of this study could be very useful and of practical application, mainly for physical education teachers and, although the studies included in this research belong to the educational field, it could also be interesting for coaches, when planning their classes or training sessions in order to look for methods and strategies where children have fun and enjoy themselves, since, at this age, learning while enjoying sports practice should be the most important thing.

CONCLUSIONS

Sport teaching models can have an impact on students' enjoyment/fun during physical education lessons. In this respect, the use of non-conventional models increases students' enjoyment/fun, which can lead to greater learning. Therefore, the methodology used by the teacher becomes a key and fundamental issue. It is worth remarking that the SE stands out when it comes to increasing students' enjoyment/fun. Finally, it seems that the traditional methodology does not manage to promote the enjoyment/fun of boys and girls in sports practice.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

MR put forward the review and meta-analysis idea, developed the inclusion and exclusion criteria, organized the article structure, selected the databases to be searched, developed the search string, searched the relevant literature, read the literature, and identified the articles included in this review and meta-analysis, and wrote the draft manuscript. FG assisted in conceptualizing the original question, reviewed and edited the drafted manuscript and provided critical guidance for integrating the introduction, results, and discussion topics. MA, MR, and FG contributed to identification of discussion topics for improving the interpretation of the meta-analysis, reviewed, and edited the manuscript. All authors contributed to the article and approved the submitted version.

REFERENCES

Alarcón, F., Cárdenas, D., Miranda, M. T., Ureña, N., and Piñar, M. I. (2010). La metodología de enseñanza en los deportes de equipo. *Rev. Invest. Educ.* 7, 91–103.

Alexander, K., and Luckman, J. (2001). Australian teachers' perceptions and uses of the Sport Education curriculum model. *Eur. Phys. Educ. Rev.* 7, 243–267. doi: 10.1177/1356336X010073002

Alexander, K., Taggart, A., and Medland, A. (1993). Sport education in physical education: try before you buy. *ACHPER National J.* 40, 16–23.

Baena-Extremera, A., Gómez-López, M., Granero-Gallegos, A., and Martínez-Molina, M. (2016). Modelo de predicción de la satisfacción y diversión en educación física a partir de la autonomía y el clima motivacional. *Univ. Psychol.* 15:39. doi: 10.11144/Javeriana.upsy15-2.mpsd

Baena-Extremera, A., Granero-Gallegos, A., Bracho-Amador C., and Pérez-Quero, F. J. (2012a). Spanish Version of the Sport Satisfaction Instrument (SSI). Adapted to physical education. *J. Psychod.* 17, 377–395. doi: 10.1387/RevPsicodidact.4037

Baena-Extremera, A., Granero-Gallegos, A., and Ortiz-Camacho, M. (2012b). Quasi-experimental study of the effect of an adventure education programme on classroom satisfaction, physical self-concept and social goals in physical education. *Psychol. Belg.* 52, 369–386. doi: 10.5334/pb-52-4-369

Balaguer, I., Atienza, F. L., Castillo, I., Moreno, Y., and Duda, J. L. (1997). "Factorial structure of measures of satisfaction/interest in sport and classroom in the case of Spanish adolescents," in *Fourth European Conference of Psychological Assessment* (Lisbon), 76.

Balshem, H., Helfand, M., Schünemann, H. J., Oxman, A. D., Kunz, R., Brozek, J., et al. (2011). GRADE guidelines: 3. Rating the quality of evidence. *J. Clin. Epidemiol.* 64, 401–406. doi: 10.1016/j.jclinepi.2010.07.015

Barkoukis, V., Ntoumanis, N., and Thøgersen-Ntoumani, C. (2010). Developmental changes in achievement motivation and affect in physical education: growth trajectories and demographic differences. *Psychol. Sport Exerc.* 11, 83–90. doi: 10.1016/j.psychsport.2009.04.008

Batez, M., Petrusic, T., Bogataj, S., and Trajkovic (2021). Effects of teaching program based on teaching games for understanding model on volleyball skills and enjoyment in secondary school students. *Sustainability* 13:606. doi: 10.3390/su13020606

Blomquist, M., Luhtanen, P., and Laakso, L. (2001). Comparison between two types of instruction in badminton. *Eur. J. Phys. Educ.* 6, 139–156. doi: 10.1080/1740898010060206

Braithwaite, R., Spray, C. M., and Warburton, V. E. (2011). Motivational climate interventions in physical education: a meta-analysis. *Psychol. Sport Exerc.* 12, 628–638. doi: 10.1016/j.psychsport.2011.06.005

Buelens, M., and Poelmans, S. A. (2004). Enriching the Spence and Robbins' typology of workaholism. *J. Organ. Change Manag.* 17, 440–458. doi: 10.1108/09534810410554470

Burgueño, R., Medina-Casaubón, J., Lirola, M., and Alcaraz-Ibáñez, M. (2016)."Diversión del alumnado de secundaria en clase de Educación Física 'Modelo de enseñanza tradicional o modelo de educación deportiva? Un estudio preliminar," in *I Congreso Internacional en Investigación y Didáctica de la Educación Física: II Jornadas de investigadores en Didáctica de la Educación Física*, eds F. Zurita, A. J. Pérez, M. Castro, and Chacón, R. (Granada: Facultad de Ciencias de la Educación, Universidad de Granada), 79–85.

Cairney, J., Matthew, Y. K., Scott-Velduizen, J. H., Steven, R. B., and Brent, E. F. (2012). Gender, perceived competence and the enjoyment of physical education in children: a longitudinal examination. *Int. J. Behav. Nutr. Phy. Act.* 9:26. doi: 10.1186/1479-5868-9-26

Capafons, A., and Silva, F. (1998). *CACIA, Cuestionario de Autocontrol Infantil y Adolescente*. Madrid: TEA Ediciones.

Carlson, T. B., and Hastie, P. A. (1997). The student social system within sport education. *J. Teach. Phy. Educ.* 16, 176–195. doi: 10.1123/jtpe.16.2.176

Carraro, A., Young, M. C., and Robazza, C. (2008). A contribution to the validation of the physical activity enjoyment scale in an Italian sample. *Soc. Behav. Persson.* 36, 911–918. doi: 10.2224/sbp.2008.36.7.911

Carron, A. V., and Brawley, L. R. (2008). "Group dynamics in sport and physical activity," in *Advances in Sport Psychology*, ed, T. S. Horn (Champaign, IL: Human Kinetics), 213–237.

Casado-Robles, C., Mayorga-Vega, D., Guijarro-Romero, S., and Viciana, J. (2020). Es efectivo el Modelo de Educación Deportiva para mejorar la deportividad y actividad física en escolares? *Rev. Int. Cienc. Deporte* 16, 180–198. doi: 10.5232/ricyde2020.06005

Cecchini, J. A., Fernández-Río, J., and Méndez-Giménez, A. (2014). Epstein's TARGET framework and motivational climate in sport: effects of a field-based, long-term intervention program. *Int. J. Sports Sci. Coa.* 9, 1325–1340. doi: 10.1260/1747-9541.9.6.1325

Cecchini, J. A., Montero, J., Alonso, A., Izquierdo, M., and Contreras, O. (2007). Effects of personal and social responsibility on fair play in sports and self-control in school-aged youths. *Eur. J. Sport Sci.* 7, 203–211. doi: 10.1080/17461390701718497

Cecchini, J. A., Montero, J., and Peña, J. V. (2003). Repercusiones del Programa de Intervención para Desarrollar la Responsabilidad Personal y Social de Hellison sobre los comportamientos de fair-play y el autocontrol. *Psicothema.* 15, 631–637.

Cervelló, E. M., Escartí, A., and Balagué, G. (1999). Relaciones entre la orientación de metas disposicional y la satisfacción con los resultados deportivos, las creencias sobre las cusas de éxito en deporte y la diversión con la práctica deportiva. *Rev. Psicol. Deporte* 8, 7–19.

Chu, T. L., and Zhang, T. (2018). Motivational processes in Sport Education programs among high school students. *Eur. Phys. Educ. Rev.* 24, 372–394. doi: 10.1177/1356336X17751231

Conde, C., Sáenz-López, P., Carmona, J., González-Cutre, D., Martínez, C., and Moreno, J. A. (2010). Validación del Cuestionario de Percepción de Soporte de la Autonomía en el Proceso de Entrenamiento (ASCQ) en jóvenes deportistas españoles. *Estud. Psicol.* 31, 145–157. doi: 10.1174/021093910804952250

Conroy, D. E., and Coatsworth, J. (2007). Assessing autonomy-supportive coaching strategies in youth sport. *Psychol. Sport Exerc.* 8, 671–684. doi: 10.1016/j.psychsport.2006.12.001

Coppola, R., Pignato, S., Sgro, F., and Lipoma, M. (2020). Effects of two different physical education teaching approaches on the levels of enjoyment in the Italian primary school students. *J. Hum. Sport Exerc.* 15, 1251–1261. doi: 10.14198/jhse.2020.15.Proc4.26

Côté, J. (1999). The influence of the family in the development of talent in sport. *Sport Psychol.* 13, 395–417. doi: 10.1123/tsp.13.4.395

Côté, J., and Hay, J. (2002). "Children's involvement in sport: a developmental perspective," in *Psychological Foundations of Sport*, eds, J. M. Silva and D. E. Stevens (Boston, MA: Allyn & Bacon), 484–502.

Crance, M. C., Trohel, J., and Saury, J. (2013). The experience of a highly skilled student during handball lessons in physical education: a relevant pointer to the gap between school and sports contexts of practice. *Phy. Educ. Sport Peda.* 18, 103–115. doi: 10.1080/17408989.2012.666790

Cruz, J., Capdevila, L., Boixados, M., Pintanel, M., Alonso, C., Mimbrero, J., et al. (1996). "Identificación de conductas, actitudes y valores relacionados con el fair play en deportistas jóvenes". In *valores sociales y deporte: Fairplay versus violencia*. *Investigaciones en Ciencias del Deporte*, ed Consejo Superior de Deportes (Madrid: Ministerio de Educación y Cultura), 37–67.

Cuevas, R., García-López, L. M., and Serra-Olivares, J. (2016). Sport education model and self-determination theory. *Kinesiology* 48, 30–38. doi: 10.26582/k.48.1.15

Cunningham, G. B. (2007). Development of the physical activity class satisfaction questionnaire (PACSQ). *Meas. Phys. Educ. Exerc. Sci.* 11, 161–176. doi: 10.1080/10913670701326443

Deci, E. L., and Ryan, R. M. (1985). *Intrinsic Motivation and Self-Determination in Human Behavior.* New York, NY: Plenum.

Deci, E. L., and Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychol. Inq.* 11:227268. doi: 10.1207/S15327965PLI1104_01

Duda, J. L., and Nicholls, J. G. (1992). Dimensions of achievement motivation in schoolwork and sport. *J. Educ. Psychol.* 84, 290–299. doi: 10.1037/0022-0663.84.3.290

Dudley, D., Okely, A., Pearson, P., and Cotton, W. (2011). A systematic review of the effectiveness of physical education and school sport interventions targeting physical activity, movement skills and enjoyment of physical activity. *Eur. Phys. Educ. Rev.* 17, 353–378. doi: 10.1177/1356336X11416734

Dyson, B. P., Griffin, L. L., and Hastie, P. A. (2004). Sport education, tactical games, and cooperative learning: theoretical and pedagogical considerations. *Quest* 56, 226–240. doi: 10.1080/00336297.2004.10491823

Elliot, A. J., Gable, S. L., and Mapes, R. R. (2006). Approach and avoidance motivation in the social domain. *Pers. Soc. Psychol. B* 32, 378–391. doi: 10.1177/0146167205282153

Emmanouel, C., Zervas, Y., and Vagenas, G. (1992). Effects of four physical education teaching methods on development of motor skill, self-concept, and social attitudes of fifth-grade children. *Percept. Motor Skill.* 74, 1151–1167. doi: 10.2466/pms.1992.74.3c.1151

Escartí, A., and Gutiérrez, M. (2001). Influence of the motivational climate in physical education on the intention to practice physical activity or sport. *Eur. J. Sport Sci.* 1, 1–12. doi: 10.1080/17461390100071406

Fairclough, S. (2003). Physical activity, perceived competence and enjoyment during secondary school physical education. *Eur. J. Phys. Educ.* 8, 5–18. doi: 10.1080/1740898030080102

Fernandez-Chinguel, J. E., Zafra-Tanaka, J. H., Goicochea-Lugo, S., Peralta, C. I., and Taype-Rondan, A. (2019). Aspectos básicos sobre la lectura de revisiones sistemáticas y la interpretación de meta-análisis. *Acta Med. Peru.* 36, 157–169. doi: 10.35663/amp.2019.362.818

Ferriz, R., González-Cutre, D., and Sicilia, A. (2015). Revision of the perceived locus of causality scale (PLOC) to include the measure of integrated regulation in physical education. *J. Sport Psychol.* 24, 329–338.

Fishbein, M., and Ajzen, I. (2010). *Predicting and Changing Behavior: The Reasoned Action Approach.* New York, NY: Psychology Press.

Forrest, G. (2015). Systematic assessment of game-centred approach practices—the game-centred approach Assessment Scaffold. *Phys. Educ. Sport Pedag.* 20, 144–158. doi: 10.1080/17408989.2013.803526

García-Bengoechea, E., Sabiston, C. M., Ahmed, R., and Farnous, M. (2010). Exploring links to unorganized and organized physical activity during adolescence: the role of gender, socioeconomic status, weight status, and enjoyment of physical education. *Res. Q. Exerc. Sport* 81, 7–16. doi: 10.1080/02701367.2010.10599623

García-López, L. M., Gutiérrez, D., Gonzalez-Villora, S., and Valero- Valenzuela, A. (2012). Cambios en la empatía, la asertividad y las relaciones sociales por la applicatión del modelo de instrutión educaction deportiva. *Rev. Psicol. Deporte* 21, 321–330.

Garn, A. C., and Cothran, D. J. (2006). The fun factor in physical education. *J. Teach. Phys. Educ*. 25, 281–297. doi: 10.1123/jtpe.25.3.281

Gil-Arias, A., Harvey, S., García-Herreros, F., González-Víllora, S., Práxedes, A., and Moreno, A. (2020). Effect of a hybrid teaching games for understanding/sport education unit on elementary students' self-determined motivation in physical education. *Eur. Phys. Educ. Rev.* 4, 1–18. doi: 10.1177/1356336X20950174

González-Cutre, D., Sicilia, A., and Moreno, J. A. (2008). Modelo cognitivo-social de la motivación de logro en educación física. *Psicothema.* 20, 642–651.

Goudas, M., Biddle, S., and Fox, K. (1994). Perceived locus of causality, goal orientations, and perceived competence in school physical education classes. *Brit. J. Educ. Psychol.* 64, 453–463. doi: 10.1111/j.2044-8279.1994.tb01116.x

Gros, B. (2009). Relación entre entretenimiento y aprendizaje: *Padres Maestros* 323, 13–16.

Guyatt, G. H., Oxman, A. D., Vist, G. E., Kunz, R., Falck-Ytter, and Alonso-coello, P. (2008). GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ.* 336, 924–926. doi: 10.1136/bmj.39489.470347.AD

Harwood, C., Spray, C. M., and Keegan, R. (2008). "Achievement goal theories in sport," in *Advances in Sport Psychology*, ed T. S. Horn (Champaign, IL: Human Kinetics), 157–185.

Hassinger-Das, B., Toub, T. S., Zosh, J. M., Michnick, J., Golinkoff, R., and Hirsh-Pasek, K. (2017). More than just fun: a place for games in playful learning / Más que diversión: el lugar de los juegos reglados en el aprendizaje lúdico. *Infanc. Aprendiz*. 40, 191–218. doi: 10.1080/02103702.2017.1292684

Hastie, P. (1996). Student role involvement during a unit of Sport Education. *J. Teach. Phys. Educ.* 16, 88–103. doi: 10.1123/jtpe.16.1.88

Hein, V., Müür, M., and Koka, A. (2004). Intention to be physically active after school graduation and its relationship to three types of intrinsic motivation. *Eur. Phys. Educ. Rev.* 10, 5–19. doi: 10.1177/1356336X04040618

Hellison, D. R. (1995). *Teaching Personal and Social Responsibility Through Physical Activity*. Champaign, IL: Human Kinetics.

Higgins, J. P., and Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Stat. Med.* 21, 1539–1558. doi: 10.1002/sim.1186

Higgins, J. P., Thompson, S. G., Deeks, J. J., and Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *BMJ* 327, 557–560. doi: 10.1136/bmj.327.7414.557

Iturbide-Luquin, L. M., and Elosua-Oliden, P. (2017). Los valores asociados al deporte: análisis y evaluación de la deportividad. *Rev. Psicodidact.* 22, 29–36. doi: 10.1016/S1136-1034(17)30041-2

Jaakkola, T., Sami, Y. P., Vassilis, B., and Jarmo, L. (2017). Relationships among perceived motivational climate, motivational regulations, enjoyment, and PA participation among finnish physical education students. *Int. J. Sport. Exerci. Psychol.* 15, 273–290. doi: 10.1080/1612197X.2015.1100209

Kirk, D. (2005). Physical education, youth sport and lifelong participation: the importance of early learning experiences. *Eur. Phys. Educ. Rev.* 11, 239–255. doi: 10.1177/1356336X05056649

Kirk, D., and MacPhail, A. (2002). Teaching games for understanding and situated learning: rethinking the Bunker-Thorpe model. *J. Teach. Phys. Educ.* 21, 177–192. doi: 10.1123/jtpe.21.2.177

Leptokaridou, E. T., Vlachopoulos, P., and Papaioannou, A. (2015). Associations of autonomy, competence, and relatedness with enjoyment and effort in elementary school physical education: the mediating role of self-determined motivation. *Hell. J. Psychol.* 12, 105–128.

Li, W., Xiang, P., Chen, Y., and Xie, X. (2017). Unit of analysis: impact of Silverman and Solmon's article on field-based intervention research in Physical Education in the U.S.A. *J. Teach. Phys. Educ.* 36, 131–141. doi: 10.1123/jtpe.2016-0169

Lis-Velado, P., and Carriedo, A. (2019). Efectos de una competición de fútbol basada en la Liga Brave sobre el fair play, las orientaciones de meta, el esfuerzo y la presión-tensión en escolares de educación primaria. *SPORT TK-Rev. EuroAmeric. Cien. Deporte* 8, 65–72. doi: 10.6018/sportk.391761

López, V., and Castejón, F. J. (2005). La enseñanza integrada técnico-táctica de los deportes en edad escolar. Explicación y bases de un modelo. *Apunts Educ. Fis. Deporte* 79, 40–48.

MacPhail, A., Gorely, T., Kirk, D., and Kinchin, G. (2008). Children's experiences of fun and enjoyment during a season of sport education. *Res. Q. Exerc. Sport* 79 344–355. doi: 10.1080/02701367.2008.10599498

Maher, C. G., Sherrington, C., Herbert, R. D., Moseley, A. M., and Elkins, M. (2003). Reliability of the PEDro scale for rating quality of randomized controlled trials. *Phys. Ther.* 83, 713–721. doi: 10.1093/ptj/83.8.713

Marcelo, C. (1992). *Aprender a enseñar.* Madrid: Ministerio español de Educación y Ciencia.

Martín-Albo, L., Núñez, J., Navarro, J., and González, V. (2006). Validación de la versión española de la escala multidimensional de orientaciones a la deportividad. *Rev. Psicol. Deporte* 15, 9–22.

Martínez-Gómez, D., Martínez-De-Haro, V., Del-Campo, J., Zapatera, B., Welk, G. J., Villagra, A., et al. (2009). Validez de cuatro cuestionarios para valorar la actividad física en adolescentes españoles. *Gac. Sani.* 23, 512–517. doi: 10.1016/j.gaceta.2009.02.013

McAuley, E., Duncan, T., and Tammen, V. V. (1989). Psychometric properties of the intrinsic motivation inventory in a competitive sport setting: a confirmatory factor analysis. *Res. Q. Exerc. Sport* 60, 48–58. doi: 10.1080/02701367.1989.10607413

Méndez-Giménez, A., Fernández-Río, J., and Cecchini-Estrada, J. (2014). Validation of the Spanish version of the friendship goals questionnaire in physical education. *Univ. Psychol.* 13, 227–237. doi: 10.11144/Javeriana.UPSY13-1.vvec

Metzler, M. (2011). *Instructional Models for Physical Education.* Scottsdale, AZ: Holcomb Hathaway.

Miller, B. M., Bartholomew, J. B., and Springer, B. A. (2005). Post-exercise affect: the effect of mode preference. *J. Appl. Sport. Psychol.* 17, 263–272. doi: 10.1080/10413200500313503

Mitchell, S. A., Oslin, J. L., and Griffin, L.:L. (2013). *Teaching Sport Concepts and Skills: A Tactical Games Approach for Ages 7 to 18.* Champaign, IL: Human Kinetics.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., and PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA. *Int. J. Surg.* 8, 336–341. doi: 10.1016/j.ijsu.2010.02.007

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., et al. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst. Rev.* 4, 1–9. doi: 10.1186/2046-4053-4-1

Montero, B. (2017). Aplicación de juegos didácticos como metodología de enseñanza: Una Revisión de la Literatura. *Pensamiento Matemático* 7, 75–92.

Moreno, J., González-Cutre, D., and Ruiz, L. M. (2009). Self-determined motivation and physical education importance. *Hum. Mov.* 10, 5–11. doi: 10.2478/v10038-008-0022-7

Moreno, J. A., and Cervelló, E. (2005). Physical self-perception in Spanish adolescents: effects of gender and involvement in physical activity. *J. Hum. Mov. Stud.* 48, 291–311.

Moreno, J. A., Moreno, R., and Cervelló, E. (2007). El autoconcepto físico como predictor de la intención de ser físicamente activo. *Psicol. Salud* 17, 261–267.

Moreno-Murcia, J. A., Coll, D., and Garzón, M. C. (2009). Preliminary validation in spanish of a scale designed to measure motivation in physical education classes: the perceived locus of causality (PLOC) scale. *Spanish J. Psychol.* 12, 327–337. doi: 10.1017/S1138741600001724

Moreno-Murcia, J. A., González-Cutre, D., and Chillón, M. (2008). Adaptation of the basic psychological needs in exercise scale to physical education. *Rev. Mex. Psicol.* 25, 295–303. doi: 10.1037/t03491-000

Moriana, J. A., Alós, F., Alcalá, R., Pino, M. J., Herruzo, J., and Ruíz-Olivares, R. (2006). Actividades extraescolares y rendimiento académico en alumnos de Educación Secundaria. *Rev. Electron. Invest. Psicoeduc.* 8, 35–46.

Morris, S. B., and DeShon, R. P. (2002). Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. *Psychol. Methods* 7, 105–125. doi: 10.1037/1082-989X.7.1.105

Mosston, M., and Ashworth, S. (1986). *Teaching Physical Education.* Columbus, OH: Merill.

Mouratidis, A., Vansteenkiste, M., Lens, W., and Sideridis, G. (2011). Vitality and interestenjoyment as a function of class-to-class variation in need-supportive teaching and pupils' autonomous motivation. *J. Educ. Psychol.* 103, 353–366. doi: 10.1037/a0022773

Myers, N. D., Prilleltensky, I., Lee, S., Dietz, S., Prilleltensky, O., McMahon, A., et al. (2019). Effectiveness of the fun for wellness online behavioral intervention to promote well-being and physical activity: protocol for a randomized controlled trial. *BMC Public Health.* 19:737. doi: 10.1186/s12889-019-7089-2

Nicholls, J. G. (1989). *The Competitive Ethos and Democratic Education.* Cambridge, MA: Harvard University.

Nordic Cochrane Centre the Cochrane Collaboration (2020). *Review Manager (RevMan) [Computer Program]*, version 5.4. Copenhagen: Nordic Cochrane Centre, The Cochrane Collaboration.

Ntoumanis, N. (2005). A prospective study of participation in optional school physical education using a Self-Determination Theory framework. *J. Educ. Psychol.* 97, 444–453. doi: 10.1037/0022-0663.97.3.444

Ortega, E., Calderón, A., Palao, J. M., and Puigcerver, C. (2008). Design and validation of a questionnaire to evaluate the perceived attitude of the professor and of a questionnaire to evaluate the attitudinal contents of the students during the physical education classes in secondary education. *Retos.* 14, 22–29.

Ortega, G., Durán, L. J., Franco, J., Giménez, F. J., Jiménez, P. J., and Jiménez, A. C. (2014). *Por una Educación REAL: Valores y deporte.* Competir para compartir valores. Madrid: Ediciones Gráficas Fundación Real Madrid.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 372:n71. doi: 10.1136/bmj.n71

Papaioannou, A. (1995). *Motivation and Goal Perspectives in Children's Physical Education*. Champaign, IL: Human Kinetics.

Papaioannou, A., Bebetsos, E., Theodorakis, Y., Christodoulidis, T., and Kouli, O. (2006). Causal relationships of sport and exercise involvement with goal orientations, perceived competence and intrinsic motivation in physical education: a longitudinal study. *J. Sports Sci.* 24, 367–382. doi: 10.1080/02640410400022060

Perlman, D. J. (2010). Change in affect and needs satisfaction for amotivated students within the sport education model. *J. Teach. Phys. Educ.* 29, 433–445. doi: 10.1123/jtpe.29.4.433

Reeve, J., and Tseng, C. M. (2011). Cortisol reactivity to a teacher's motivating style: the biology of being controlled versus supporting autonomy. *Motiv. Emot.* 35, 63–74. doi: 10.1007/s11031-011-9204-2

Reeve, J., Vansteenkiste, M., Assor, A., Ahmad, I., Hyeon, S., Jang, H., et al. (2014). The beliefs that underlie autonomy-supportive and controlling teaching: a multinational investigation. *Motiv. Emot.* 38, 93–110. doi: 10.1007/s11031-013-9367-0

Riera, J. (2010). *Fundamentos del Aprendizaje de la Técnica y la Táctica Deportivas*. Barcelona: Inde.

Roberts, G. C., and Balagué, G. (1991). "The development and validation of the Perception of Success Questionnaire," in *Paper presented at the FEPSAC Congress* (Cologne).

Roberts, G. C., Treasure, D. C., and Balagu,é, G. (1998). Achievement goals in sport: the development and validation of the perception of success questionnaire. *J. Sports Sci.* 16, 337–347. doi: 10.1080/02640419808559362

Ryan, R. M. (1982). Control and information in the intrapersonal sphere: an extension of cognitive evaluation theory. *J. Pers. Soc. Psychol.* 43, 450–461. doi: 10.1037/0022-3514.43.3.450

Ryan, R. M., and Connell, J. P. (1989). Perceived locus of causality and internalization: examining reasons for acting in two domains. *J. Pers. Soc. Psychol.* 57, 749–761. doi: 10.1037/0022-3514.57.5.749

Sallis, J. F., and McKenzie, T. L. (1991). Physical education's role in public health. *Res. Q. Exerc. Sport* 62, 124–137. doi: 10.1080/02701367.1991.10608701

Sánchez, J., and Núñez, J. L. (2007). Análisis preliminar de las propiedades psicométricas de la versión española de la escala de necesidades psicológicas básicas en el ejercicio físico. *Rev. Iberoamericana Psicol. Ejercicio Deporte* 2, 83–92.

Sánchez-Oliva, D., Leo, F. M., Amado, D., González-Ponce, I., and García-Calvo, T. (2012). Desarrollo de un cuestionario para valorar la Motivación en Educación Física. *Rev. Iberoamericana Psicol. Ejercicio Deporte* 7, 227–250.

Scanlan, T. K., Carpenter, P. J., Lobel, M., and Simons, J. P. (1993). Sources of enjoyment for youth sport athletes. *Pediatr. Exerc. Sci.* 5, 275–285. doi: 10.1123/pes.5.3.275

Scanlan, T. K., and Lewthwaite, R. (1986). Social psychological aspects of competition for male youth sport participants: predictors of enjoyment: IV. *J. Sport Psychol.* 8, 25–35. doi: 10.1123/jsp.8.1.25

Schembri, R., Coppola, R., Tortella, P., and Sgr,ò, F. (2021). Improving enjoyment during physical education lesson in primary school students. *J. Hum. Sport Exerc.* 16, S735–S742. doi: 10.14198/jhse.2021.16.Proc2.59

Serra, J., García-López, L. M., and Sánchez-Mora, D. (2011). El juego modificado, recurso metodológico en el fútbol de iniciación. *Retos* 20, 37–42.

Sicilia, A., Ferriz, R., Trigueros, R., and González-Cutre, D. (2014). Spanish adaptation and validation of the Physical Activity Class Satisfaction Questionnaire (PACSQ). *Univ. Psychol.* 13, 1321–1332. doi: 10.11144/Javeriana.UPSY13-4.ayve

Spittle, M., and Byrne, K. (2009). The influence of Sport Education on student motivation in physical education. *Phys. Educ. Sport Peda.* 14, 253–266. doi: 10.1080/17408980801995239

Stewart, A., Marfell-Jones, M., Olds, T., and De Ridder, J. (2011). *International Standards for Anthropometric Assessment.* Lower Hutt: ISAK.

Thomas, J. R., and Nelson, J. K. (2007). *Métodos de Investigación en Actividad Física.* Barcelona: Paidotribo.

Tomás, I. (1998). *Equivalencia Psicométrica de la Traducción al Español del PSDQ* (Unpublished doctoral dissertation). University of Valencia, Spain.

Treasure, D. C., and Roberts, G. C. (2001). Students' perceptions of the motivational climate, achievement beliefs, and satisfaction in physical education. *Res. Q. Exerc. Sport* 72, 165–175. doi: 10.1080/02701367.2001.10608946

Urrútia, G., and Bonfill, X. (2010). PRISMA declaration: a proposal to improve the publication of systematic reviews and meta-analyses. *Med. Clin.* 135, 507–511. doi: 10.1016/j.medcli.2010.01.015

Valle, A., González, R., and Cuevas, R. (1997). Patrones motivacionales en estudiantes universitarios: características diferenciales. *Rev. Integr. Educ.* 15, 125–146.

Vallerand, R. J. (2001). "A hierarchical model of intrinsic and extrinsic motivation in sport and exercise," in *Advances in Motivation in Sport and Exercise*, ed Roberts, G. C. (Champaign, IL: Human Kinetics), 263–319.

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Briere, N. M., Senecal, C., and Vallieres, E. F. (1992). The academic motivation scale: a measure of intrinsic, extrinsic, and amotivation in education. *Educ. Psychol. Meas.* 52, 1003–1017. doi: 10.1177/0013164492052004025

Viciana, J., Casado-Robles, C., Pérez-Macías, L., and Mayorga-Vega, D. (2020). A Sport Education teaching unit as a citizenship education strategy in Physical Education. A group-randomized controlled trial. *Retos* 38, 44–52. doi: 10.47197/retos.v38i38.73546

Vlachopoulos, S. P., and Michailidou, S. (2006). Development and initial validation of a measure of autonomy, competence, and relatedness in exercise: the basic psychological needs in exercise scale. *Meas. Phys. Educ. Exerc. Sci.* 10, 179–201. doi: 10.1207/s15327841mpee1003_4

Wallhead, T. L., Garn, A. C., and Vidoni, C. (2014). Effect of a sport education program on motivation for physical education and leisure-time physical activity. *Res. Q. Exerc. Sport* 85, 478–487. doi: 10.1080/02701367.2014.961051

Wallhead, T. L., and Ntoumanis, N. (2004). Effects of a sport education intervention on students' motivational responses in physical education. *J. Teach. Phys. Educ.* 23, 4–18. doi: 10.1123/jtpe.23.1.4

Walling, M. D., Duda, J., and Chi, L. (1993). The perceived motivational climate in sport questionnaire: construct and predictive validity. *J. Sport Exerc. Psy.* 15, 172–183. doi: 10.1123/jsep.15.2.172

Wang, C., Chatzisarantis, N., Spray, C., and Biddle, S. (2002). Achievement goal profiles in school physical education: differences in self-determination, sport ability beliefs, and physical activity. *Brit. J. Educ. Psychol.* 72, 433–445. doi: 10.1348/000709902320634401

Wiersma, L. D. (2001). Conceptulization and development of the sources of enjoyment in youth sport questionnaire. *Meas. Phys. Educ. Exerc. Sci.* 5, 153–177. doi: 10.1207/S15327841MPEE0503_3

Yu, J. J., Burnett, A. F., and Sit, C. H. (2018). Motor skill interventions in children with developmental coordination disorder: a systematic review and meta-analysis. *Arch. Phys. Med. Rehab.* 99, 2076–2099. doi: 10.1016/j.apmr.2017.12.009

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Psychology

BRIEF RESEARCH REPORT
published: 14 September 2021
doi: 10.3389/fpsyg.2021.708725

Running Performance of High-Level Soccer Player Positions Induces Significant Muscle Damage and Fatigue Up to 24 h Postgame

Lucas Albuquerque Freire[1]*, Michele Andrade de Brito*[1]***, *Natã Sant'anna Esteves*[1]*, Márcio Tannure*[1]*, Maamer Slimani*[2]*, Hela Znazen*[3]*, Nicola Luigi Bragazzi*[4]*, Ciro José Brito*[5]*, Dany Alexis Sobarzo Soto*[6]*, Daniel Gonçalves*[1] *and Bianca Miarka*[1]

[1] Department of Fights, Postgraduate Program in Physical Education, School of Physical Education and Sports, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil, [2] Department of Neuroscience, Rehabilitation, Ophthalmology, Genetics, Maternal and Child Health (DINOGMI), Section of Psychiatry, University of Genoa, Genoa, Italy, [3] Department of Physical Education and Sport, College of Education, Taif University, Taif, Saudi Arabia, [4] Laboratory for Industrial and Applied Mathematics, Department of Mathematics and Statistics, York University, Toronto, ON, Canada, [5] Postgraduate Program in Physical Education, School of Physical Education and Sports, Federal University of Juiz de Fora, Juiz de Fora, Brazil, [6] Escuela de Kinesiología, Facultad de Salud, Universidad Santo Tomás, Santiago, Chile

OPEN ACCESS

Edited by:
Daniel Castillo, Universidad Isabel I de Castilla, Spain

Reviewed by:
Javier Raya-González, Universidad Isabel I de Castilla, Spain
Miguel-Angel Gomez-Ruano, Polytechnic University of Madrid, Spain

***Correspondence:**
Michele Andrade de Brito
mybritto@hotmail.com

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *12 May 2021*
Accepted: *09 August 2021*
Published: *14 September 2021*

Citation:
Freire LA, Brito MA, Esteves NS, Tannure M, Slimani M, Znazen H, Bragazzi NL, Brito CJ, Soto DAS, Gonçalves D and Miarka B (2021) Running Performance of High-Level Soccer Player Positions Induces Significant Muscle Damage and Fatigue Up to 24 h Postgame. Front. Psychol. 12:708725. doi: 10.3389/fpsyg.2021.708725

This study aimed to determine the impact of a soccer game on the creatine kinase (Ck) response and recovery and the specific Global Positioning System (GPS)-accelerometry-derived performance analysis during matches and comparing playing positions. A sample composed of 118 observations of 24 professional soccer teams of the Brazil League Serie A was recruited and classified according to playing positions, i.e., Left/Right Defenders (*D* = 30, age: 25.2 ± 5.8 years, height: 187 ± 5.5 cm, weight: 80 ± 5.8 kg), Offensive Midfielders (OM = 44, age: 25.1 ± 0.2 years, height: 177 ± 0.3 cm, weight: 73 ± 1.2 kg), Forwards (*F* = 9, age: 25.1 ± 0.2 years, height: 176.9 ± 4.3 cm, weight: 74.5 ± 2.1 kg), Left/Right Wingers (*M* = 23, age: 24.5 ± 0.5 years, height: 175 ± 1.1 cm, weight: 74 ± 4.4 kg), and Strikers (*S* = 12, age: 28 ± 0.2 years, height: 184 ± 1.0 cm, weight: 80 ± 1.4 kg). Blood Ck concentration was measured pre-, immediately post-, and 24 h postgame, and the GPS-accelerometry parameters were assessed during games. Findings demonstrated that Ck concentrations were higher at all postgame moments when compared with pregame, with incomplete recovery markers being identified up to 24 h after the game (range: 402–835 U/L). Moreover, Midfielders (108.6 ± 5.6 m/min) and Forwards (109.1 ± 8.3 m/min) had a higher relative distance vs. other positions (100.9 ± 10.1 m/min). Strikers [8.2 (8.1, 9.05) load/min] and Defenders [8.45 (8, 8.8) load/min] demonstrated lower load/min than Wingers [9.5 (9.2, 9.8) load/min], Midfielders [10.6 (9.9, 11.67) load/min], and Forwards [11 (10.65, 11, 15) load/min]. These results could be used to adopt specific training programs and recovery strategies after match according to the playing positions.

Keywords: muscle damage, fatigue, muscle strength, sports, task performance and analysis, external loads

INTRODUCTION

Studying the determinants of performance outcomes and recoveries of professional soccer players, such as sprints, accelerations, decelerations, changes in direction, jump movement patterns, technical skills, and tactical actions associated with high-intensity efforts translated into metrics, could potentially be useful to inform the construction of specific conditioning drills in an evidence-based fashion (Ade et al., 2016). In quest of best performance, soccer athletes, coaches, and physical trainers have to decide how and when they have to invest their energy (Akubat et al., 2018). The performance analysis of soccer matches has been increasingly utilized during the previous years for this purpose (Sarmento et al., 2008; Enes et al., 2021). Due to the difficulties and challenges in conducting physiological measurements during a match, studies interested in the time-motion analysis used running performance [Global Positioning System and Local Positioning System (GPS/LPS)] and factors affecting performance outcomes to infer the metabolic profiles of soccer matches (Anderson et al., 2019; Gantois et al., 2020).

The studies of performance analyses showed that soccer match requires many physically demanding performances. The available scholarly literature computed a total and relative distance covered during the game between ∼8,000 and 10,500 m, with a range of ∼100–120 m/min per match (Reinhardt et al., 2019). The low-intensity running performance has not been found determinant in intra-game comparisons, as shown in the published studies (Di Salvo et al., 2010; Modric et al., 2019). In contrast, besides scoring the goals, accelerations, decelerations, the number of sprints and distance covered greater than 18 km/h, and other running metrics variables seem to be the key factors to succeed in professional soccer matches (Mara et al., 2015; Abbott et al., 2018).

Physical performance during a soccer match is highly variable and depends on many factors, such as match intensity, period of the season, age, and playing positions, among others. Several investigations have studied the physical demands of a soccer match across playing positions. The majority of them categorized positions into defenders, midfielders, and attackers. Felipe et al. (2019) reported that defenders covered greater total distance (10,307.33 ± 1,206.33) when compared with midfielders (7,705.06 ± 3,201.10) and attackers (7,240.61 ± 3,411.31) (Felipe et al., 2019). In contrast, another study showed that defenders had lower total absolute distance and work rates when compared with midfielders in the first half and midfielders and attackers in the second half (Vescovi and Favero, 2014). Regarding moderate- and high-intensity running, contradictory results have been reported in the literature (Hewitt et al., 2014).

More in detail, when specifically categorizing the playing positions, central defenders performed lower total distance covered, high-speed running (HSR), and very-high-speed running (VHSR) compared with full-backs, central midfielders, external midfielders, and forwards. Center-backs reported the lowest values for total distance covered (Mendez-Villanueva et al., 2012) and high-intensity activities (Andrzejewski et al., 2009; Buchheit et al., 2010; Brito et al., 2017; Varley et al., 2017); midfielders and second attackers performed the highest total distance covered; wide midfielders and attackers demonstrated the highest peak game speeds and frequency of high-intensity activities (Buchheit et al., 2010; Al Haddad et al., 2015; Izzo and Varde'i, 2017).

Furthermore, participation in a soccer match can lead to acute and residual fatigue, characterized by a decline in physical performance over the following hours, which can persist even for days (Aquino et al., 2016). The magnitude of these disturbances increases within the first 24 h after a competition with peaks between 24 and 48 h post-match (Aquino et al., 2016). Together with a decrease in running performance, the potential insurgence of muscle damage and the increased levels of intramuscular enzymes, such as creatine kinase (Ck) and inflammatory/immunological biomarkers, are reported following soccer competition (Russell et al., 2016; Oliveira et al., 2019). Some studies have found a significant correlation between running performance outcomes and muscle damage markers (e.g., muscle soreness, Ck) at 24, 48, and 72 h after the soccer matches (Russell et al., 2016; Silva et al., 2018). More in detail, Russell et al. (2016) investigated, from a quantitative standpoint, the associations between GPS/LPS-accelerometry findings (i.e., high-intensity distance covered, HSR distance, and the number of sprints carried out) and changes in Ck levels and peak power output during the execution of countermovement jumps 24 and 48 h after the match in a sample of 15 English Premier League Reserve team players. Statistically significant correlations with coefficients ranging from 0.363 to 0.410 were found 24 h but not 48 h post-match. Silva et al. (2018) performed a systematic review and meta-analysis concerning the match-induced fatigue and related recovery profiles of soccer players, taking into account several parameters (i.e., physiological, neuromuscular, biochemical/endocrinological, perceptual, and technical). The authors pooled together 77 studies and computed 1,196 effect sizes (ESs), finding small-to-large variations in the variables under study. These changes could be detected, differently from the previous study (Russell et al., 2016), until 72 h post-match, indicating a persistence of the muscle damage in terms of biochemical, inflammatory, and immunological parameters. These contrasting findings can be reconciled, assuming that some variables (such as those endocrinological/hormonal and technical) can be fully recovered in the short term after the match; for others, the process and dynamics of homeostatic balance are more complex, requiring more than 72 h.

It is well known that the magnitude of muscle damage and the other physiological alterations elicited by matches are associated with oscillations in Ck levels (Coppalle et al., 2019) and related running performance can be assessed with *ad hoc* performance analytical tools (Milanović et al., 2020; Enes et al., 2021; Strauss et al., 2019). Furthermore, soccer matches can affect the players differently depending on their playing positions (Abbott et al., 2018). However, the influence of this variable has been relatively overlooked in the available scholarly literature. Furthermore, with the positional difference of physical demand during soccer matches (Abbott et al., 2018), information about the effect of a soccer match on muscle damage postgame was lacking. Consequently, a comprehensive assessment in terms of positional differences of the muscle damage post-match of elite soccer players is necessary to inform applied practitioners working with soccer players to: (1) tailor and personalize interventions based on the specific needs of athletes, rather than relying on a "one-size-fits-it-all" approach; (2) better adopt position-specific recovery strategies; (3) appropriate time between match and session training; and (4) reduce the risk of injuries and achieve optimal performance outcomes. We formulated the working hypotheses that: (1) there is a difference in terms of performance outcomes among players of different playing positions; and (2) game load can impact Ck responses after competition until 24 h after the match. Therefore, this study was devised to fill in this gap in knowledge and aimed to determine the impact of a soccer game on the Ck response, recovery, and specific running performance outcomes, stratifying by playing position.

MATERIALS AND METHODS

Sample

From an initial list of 800 soccer matches performances, this study randomly selected the performances of 118 athletes from professional soccer teams of Rio de Janeiro during the 2018 and 2019 championship seasons. During the games, athletes were classified as Left/Right Defenders (D = 30, age: 25.2 ± 5.8 years, height: 187 ± 5.5 cm, and weight: 80 ± 5.8 kg), Offensive Midfielders (OM = 44, age: 25.1 ± 0.2 years, height: 177 ± 0.3 cm, and weight: 73 ± 1.2 kg), Forwards (F = 9, age: 25.1 ± 0.2 years, height: 176.9 ± 4.3 cm, and weight: 74.5 ± 2.1 kg), Left/Right Wingers (W = 23, age: 24.5 ± 0.5 years, height: 175 ± 1.1 cm, and weight: 74 ± 4.4 kg), and Strikers (S = 12, age: 28 ± 0.2 years, height: 184 ± 1.0 cm, and weight: 80 ± 1.4 kg). We considered the level and locations of opponents: 39 international games of *Copa Libertadores da América*, 58 national games of *Brasileirão Série A*, and 26 state games of *Campeonato Carioca de Futebol*, with 28 teams in different rounds or championship phases, with competitions occurring once per week. The performance-analysis-related data were collected at single time points while the Ck level was studied before, after, and 24 h after the game. Therefore, a total of 354 samples of Ck concentration of all professional soccer players were analyzed in three moments as follows: first, before the game (Ck n = 118); second, after the game (Ck n = 118); and third, after 24 h of the game (Ck n = 118). The sample size was enough to compute estimates with 95% CI and 5% of margin of error.

Each athlete had a minimum of 6 days of rest from the previous match to prevent stress interference, competed in national and international representative championships once (∼90 min) per week, and had been regularly training 2 h of technical and tactical aspects 4–7 times a week and 1 h of physical preparation 2–3 times a week. Therefore, all participants were from the Brazil league and had previous experience with professional soccer events, rules, and procedures used during the event.

The inclusion criteria were as follows: (1) being from the Brazilian league; (2) having played during ∼85% of the game; (3) having a minimum of 6 days of rest from their previous match to prevent stress interference; (4) having competed in national and international representative championships once (∼90 min) per week; and (5) 2 h of regular training of technical and tactical aspects 4–7 times a week and 1 h of physical preparation 2–3 times a week. We excluded participants who played games for more than 90 min, substituted players, and goalkeepers.

This study was approved by the Local Committee of Ethics in Research (No. 13846919.8.0000.5257), following the rules of resolution of the National Health Council and in accordance with the WMA Declaration of Helsinki. Then, the volunteers (age: >18 years) were contacted by the researchers in such a way to be informed about the aims and procedures of the study and signed an informed consent form to participate in the data collection. Measurements were performed before, after, and 24 h after the game. No modifications were made in the training, nutritional, or hydration status of participants, and they maintained a passive recovery time pattern of 24 h without training efforts between the game, postgame, and 24 h postgame.

Physical Performance Demands

The subjects wore a GPS unit (Catapult Innovations, Scoresby, Australia) during each trial (Jennings et al., 2010b). The performance analyses of the professional soccer players were monitored using a portable 5-Hz GPS unit (Catapult, Melbourne, Australia) during games. The GPS unit was positioned *via* an elasticized shoulder harness to sit between the scapulae of the player at the base of the cervical spine (Petersen et al., 2009a). The GPS unit was activated and a GPS satellite lock was established for at least 15 min before the player taking the field, as per the recommendations of the manufacturer (Petersen et al., 2009b). The recorded information was downloaded after each session using Catapult Sprint software (Catapult Innovations, Melbourne, Australia) for analysis. Once downloaded, the competition data were edited and split into two 45-min halves (Abbott et al., 2018).

Only subjects completing the entire match were included in the analysis process. The mean number of satellites and the horizontal dilution of position were recorded during the data collection (Abbott et al., 2018). The performance analysis followed a preceding protocol (Abbott et al., 2018). The total distance (m), i.e., distance traveled during all the game; total distance by minute; percentage of distance traveled, low-intensity running and jogging (<14 km/h), running (>14 km/h), and sprinting (>18 km/h), distance and number of sprints (>18 and >24 km/h), maximum speed (km/h), number of accelerations (>9 km/h), and deceleration (<9 km/h), jumps (>30 cm), and efforts (i.e., accelerations, deceleration, and jumps) were the performance analysis factors assessed during professional soccer games with ∼90 min of durations (Abbott et al., 2018).

Ck Measure

Blood Ck concentration was measured pre-, post-, and 24 h postgame by reflectance photometry at 37°C using the Reflotron Analyzer Plus (Reflotron Plus, Roche, Germany), previously calibrated. To reduce errors, only one evaluator was responsible for these collected data. A lancet device with an automatic trigger was used for puncturing the finger after finger asepsis using 70% ethyl alcohol, and the blood was drained into a strip for specific examination (using heparinized capillary strips). A blood sample

(32 μl) was immediately pipetted into a Ck test strip, which was introduced into the instrument. The absolute values of Ck (U/L) were used for analysis, according to the study of Aquino et al. (2016).

Statistical Analysis

The descriptive data are presented as mean and SD, using the coefficient of variance (CV, %) as the measure of variability. The Kolmogorov–Smirnov test (K-S) was used to determine the normal distribution of the data, considering $p \leq 0.05$. A repeated measure ANOVA was performed to verify the Ck modifications, and a generalized estimating equation (GEE) mixed-linear model accounting for individual (random) effect was conducted, considering the level and location of the opponent (International competitions in South America × National competitions in Brazil × State competitions in Rio de Janeiro) as a control variable. The ES was calculated using eta-squared and interpreted as follows: small ($0.01 < ES < 0.06$), medium ($0.06 < ES < 0.14$), or large ($ES > 0.14$). The significance level of $p \leq 0.05$ was used. All analyses were conducted using SPSS for Windows software (version 20.0; SPSS, Inc., Chicago, IL, United States).

RESULTS

Table 1 shows the descriptive analysis of distance and load during the game, with the total/minute ratio separated by the position of the player.

Total distance had differences ($F = 14.42$, $p \leq 0.001$, ES = 0.63, i.e., large ES); the *S* and *D* groups had a shorter total length than all groups, and *F* had a shorter total length than *M* and *W* groups ($p \leq 0.001$ for all comparisons).

Statistically significant effects were observed between the positions of players in the distance/min ($F = 15.06$, $p \leq 0.001$, ES = 0.64, i.e., large ES), where *M* and *F* had higher values than all other groups ($p \leq 0.001$ for all comparisons).

The total load also showed differences ($F = 22.39$, $p \leq 0.001$, ES = 0.73, i.e., large ES); the *S* and *D* groups had a lower total load than all the other groups, and *F* had a lower total load than *M* ($p \leq 0.001$ for all comparisons).

The comparisons also demonstrated effects in load/min ($F = 19.59$, $p \leq 0.001$, ES = 0.70, i.e., large ES). The *S* and *D* groups had a lower load ratio than all the other groups ($p \leq 0.001$ for all comparisons).

Figure 1 shows the sprint frequencies per soccer match.

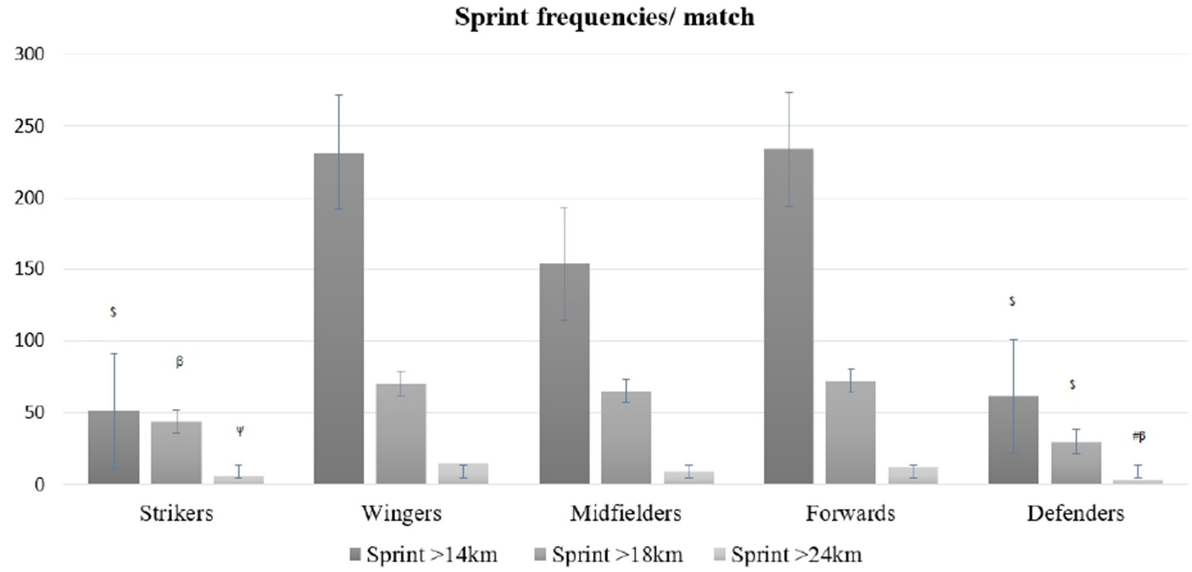
Effects were also observed in sprint frequencies above 14 km/h ($F = 10.28$, $p \leq 0.001$, ES = 0.55, i.e., large ES), where *S* and *D* had lower frequencies than all other groups ($p \leq 0.001$ for all comparisons), and *S* had higher frequencies than *D* ($p = 0.015$).

Moreover, the analysis presented differences in sprint frequencies above 18 km/h between the positions of players ($F = 17.65$, $p \leq 0.001$, ES = 0.64, i.e., large ES), where *S* and *D* had lower frequencies than all other groups ($p \leq 0.001$ for all comparisons), and *S* had higher frequencies than *D* ($p = 0.015$).

TABLE 1 | Descriptive analysis of behavior and performance factors, considering each player's position.

Factors/ Position group	Strikers (n = 12) M ± SD	CV%	Wingers (n = 23) M ±SD	CV%	Midfielders (n = 44) M ± SD	CV%	Forwards (n = 9) M ± SD	CV%	Defenders (n = 30) M ± SD	CV%
Total Distance (m)	$7359.0 \pm 1391.1^{*\#\beta}$	18.9	9199.8 ± 662.1	7.2	10354.1 ± 757.3	7.3	$8155.6 \pm 1058.6^{*\beta}$	13	$7830.6 \pm 1227.5^{*\beta}$	15.7
Distance (m)/min	$94.3 \pm 1.2^{*\psi}$	1.3	$99.6 \pm 5.8^{*\psi}$	5.8	108.7 ± 6.1	5.6	103.4 ± 7.4	8	$90.4 \pm 7.8^{*\psi}$	8.6
Total Load (index)	$654.7 \pm 118.7^{\$}$	18	$871.7 \pm 49.0^{\psi}$	5.6	1047.1 ± 119.0	11.3	1005.0 ± 48.1	4.8	$752.0 \pm 106.8^{\$}$	14.1
Load/ min (index/min)	$8.3 \pm 0.58^{\$}$	6.9	9.3 ± 0.52	5.7	11.1 ± 1.3	12	10.5 ± 0.71	6.7	$8.8 \pm 0.8^{\$}$	9
Speed max (km/h)	29.3 ± 1.8	6.2	31.2 ± 1.8	5.8	29.5 ± 2.0	6.7	$29.2 \pm 2.1^{\$}$	7.2	28.2 ± 2.4	8.6
Acceleration (frequency)	$34.2 \pm 7.3^{\#}$	21	$37.1 \pm 8.6^{\#\psi}$	23	$31.3 \pm 7.5^{\#}$	24	38.6 ± 7.9	20.4	25 ± 6.6	26
Deceleration (frequency)	33.6 ± 9.4	28	41.7 ± 9.0	22	37.1 ± 9.6	25.9	40.4 ± 6.4	23	$23.5 \pm 5.7^{\$}$	24
Jumps (frequency)	$8.8 \pm 3.4^{\#\psi}$	39	12.5 ± 4.0	32	$10.9 \pm 5.8^{\#\psi}$	53	11 ± 3.5	32	15 ± 4.7	31
Explosive efforts (frequency)	97 ± 13.8	14	96.4 ± 1.5	1.5	93.2 ± 8.0	8.6	$79 \pm 14.1^{\$}$	17.7	$96.6 \pm 1.4^{\$}$	1.4

$^{\$}$Significant differences from all other groups; *significant differences from Midfielders; $^{\#}$significant differences from Defenders; $^{@}$significant differences from Strikers; $^{\psi}$significant differences from Forwards; $^{\beta}$significant differences from Wingers. $p < 0.05$ for all comparisons.



Factors/ Position group	Strikers (n=12)		Wingers (n=23)		Midfielders (n=44)		Forwards (n=9)		Defenders (n=30)	
	M±SD	CV%	M±SD	CV%	M±SD	CV%	M±SD	CV%	M±SD	CV%
Sprint >14km (frequency)	51.3±51.5$	47%	231.8±36.4	16%	153.6±31.5	20%	234.5±63.0	19%	61.2±39.9$	65%
Sprint >18km (frequency)	43.8±20.7β	47%	70.3±13.2	19%	65.2±12.9	20%	72±7.6	25%	30±9.6$	32%
Sprint >24km (frequency)	6.5±4.3ψ	66%	15.1±5.6	37%	9.0±4.6	53%	12.2±4.7	30%	3.8±2.8#β	73%

FIGURE 1 | Sprint frequencies by player position. $Significant differences from all other groups; #significant differences from Defenders; ψsignificant differences from Forwards; βsignificant differences from Wingers, $p < 0.05$ for all comparisons.

Effects were also observed in sprint frequencies above 24 km/h ($F = 7.72$, $p \leq 0.001$, ES = 0.48, i.e., large ES), where *D* had lower frequencies than all groups, while *M* had lower frequencies than *S* and *W* ($p \leq 0.001$ for all comparisons).

Furthermore, the analysis verified differences in maximal velocity comparisons ($F = 2.41$, $p = 0.007$, ES = 0.23, i.e., large ES), *D* had lower speed than *W* ($p \leq 0.001$).

The comparison also showed differences in the deceleration of sprints ($F = 7.28$, $p \leq 0.001$, ES = 0.46, i.e., large ES), where *D* had a lower frequency than all other groups ($p \leq 0.001$ for all comparisons).

Additionally, the analysis observed effects in the acceleration of sprints between the positions of players ($F = 3.79$, $p \leq 0.001$, ES = 0.31, i.e., large ES), where *D* had a lower frequency than *S* ($p = 0.005$), *W* ($p \leq 0.001$), *M* ($p = 0.009$), and *F* ($p = 0.003$), and *M* had a lower frequency of acceleration than *W* ($p = 0.012$).

Besides, effects were observed in jump frequencies when comparing the positions of players ($F = 2.46$, $p = 0.006$, ES = 0.23, i.e., large ES), where *S* and *M* had lower frequency than *D* ($p = 0.003$ and $p = 0.004$, respectively).

Finally, the comparisons indicated differences in explosive effort frequencies ($F = 36.43$, $p \leq 0.001$, ES = 0.56, i.e., large ES); *D* had a lower frequency than other groups ($p \leq 0.001$ for all), while *M* had lower values than *F* ($p = 0.032$).

Figure 2 shows Ck values. Significant differences were observed between time points when comparing Ck ($X^2 = 114.67$, $p \leq 0.001$, ES = 0.59, i.e., large ES). The Ck baseline (255 U/L) time point had lower values than postgame (718.5 U/L, $p \leq 0.001$) and 24 h postgame (560.0 U/L, $p \leq 0.001$). Postgame presented higher Ck values than the other time points ($p \leq 0.001$ for all comparisons). The positions of players demonstrated differences when comparing Ck baselines ($X^2 = 30.56$, $p \leq 0.001$, ES = 0.37, i.e., large ES), where *D* (158.0 U/L) had lower values than *W* (341.0 U/L, $p = 0.003$) and *M* (255.0 U/L, $p \leq 0.001$). Significant differences were observed in Ck postgame ($X^2 = 19.89$, $p \leq 0.001$, ES = 0.218, i.e., large ES) and in Ck 24 h postgame ($X^2 = 20.55$, $p \leq 0.001$, ES = 0.223, i.e., large ES), where *D* (522.5 and 325.0 U/L) had lower values than *M* (718.5 and 560.0 U/L, $p \leq 0.001$ for all comparisons) in both Ck postgame and 24 h postgame, respectively.

DISCUSSION

This study aimed to determine the impact of a soccer game on the Ck response, recovery, and specific running performance outcomes during professional soccer games by comparing playing positions. The main results demonstrated that Ck

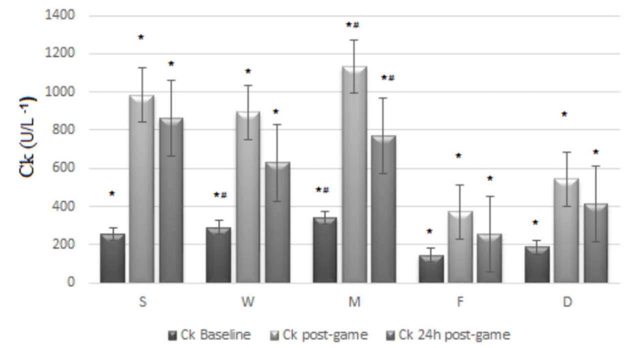


FIGURE 2 | Ck (U/L^{-1}) baseline, post and 24 h post game, by player's position. *Significant differences from all other moments; #significant differences from Defenders; $p < 0.05$ for all comparisons.

concentrations were higher at all postgame time points when compared with pregame, with the highest concentrations being observed after the game. Incomplete recovery markers were also identified up to 24 h after the game, especially for midfielders. Significant effects were observed between the positions of players when comparing performance indicators, in which offensive midfielders had higher total and relative distances covered and higher loads during high-level soccer games. The strikers had a lower percentage of submaximum, maximum, and up to maximum limit efforts during the game than other groups. At the same time, middle athletes demonstrated a higher frequency of sprints above 24 km/h, the number of jumps (<30 cm), and the total frequency of explosive efforts. The interactions between the positions and the level and location of opponents were observed for the total distance, relative distance, total load, sprint frequencies above 18 km/h, and decelerations, with higher values in international competitions in South America than at the state level in Rio de Janei ro.

This study showed that midfielders and forwards covered higher distances than other playing positions. This finding is in line with previous studies, which reported a greater distance covered by midfielders, followed by forwards and defenders during a soccer match play (Mohr et al., 2003; Di Salvo et al., 2010; Djaoui et al., 2013; Vescovi and Favero, 2014). The same data were reported in some investigations assessing the French First League, the Spanish La Liga, and the English FA Premier League (Dellal et al., 2010, 2011). For example, Dellal et al. (2010, 2011) investigated the physical activities of elite soccer players across six playing positions. The authors showed that the covered total distances were greater in midfielders (i.e., central defensive midfielders, wide midfielders, and central attacking midfielders) than forwards, central defenders, and full-backs. Furthermore, when analyzing running performance during German *Bundesliga* over three seasons (i.e., 2014/2015, 2015/2016, and 2016/2017) according to five positional roles, Chmura et al. (2018) reported that forwards covered the longer distance in won matches than in drawn and lost matches, while wide midfielders similarly ran a significantly longer distance in drawn and won matches than in lost matches. This finding is also confirmed by Andrzejewski et al. (2019) in their study of 1,178 soccer players taking part in the Polish Premier League matches during the four seasons (from 2010 to 2014). Other data that may support this finding reported that elite midfielders have the biggest intermittent endurance capacity and the maximum rate of oxygen consumption (VO_{2max}) than forwards and defenders (Slimani and Nikolaidis, 2019). This could be explained by the fact that midfielders played in an important position that linked defenders and attackers, which requires them to perform a repetitive moving back and forth between the attack and defense. Practitioners would adopt appropriate specific training plans that adequately elicit heightened cardiovascular demands in midfielders compared with other playing positions.

This study reported that midfielders had a higher sprint frequency and absolute distance sprinting than defenders and attackers. Accordingly, Di Salvo et al. (2010) analyzed 67 European matches (European Champions League and UEFA Cup) over four seasons and compared running performance among five playing positions. The authors found that wide midfielders performed a higher total number of sprints and total sprint distance than other playing positions. In contrast, other studies have shown that wide defenders and attackers covered a significantly greater distance and sprint time than midfielders (Mohr et al., 2003; Rampinini et al., 2008). Other studies by Dellal et al. (2010, 2011) reported that forwards sprinted the greatest distance than other playing positions during the French First League, the Spanish LaLiga, and the English FA Premier League soccer matches. These contradictions may be explained by the fact that each team has a specific playing formation, opposition level, tactics, and physical fitness of players (Al'Hazzaa et al., 2001; Aquino et al., 2017; Sarmento et al., 2018; Slimani et al., 2019; Arjol-Serrano et al., 2021). Therefore, it seems that practitioners would adopt position-specific training programs for their players.

Regarding the acceleration and deceleration according to playing positions, our study found that left/right defenders had lower acceleration and deceleration frequencies than the left/right midfielders, wingers, and strikers. These data confirm the data collected by previous authors (Vigne et al., 2010), who analyzed the activity profiles of players of a top-class team in the Italian National Football League over the course of a season and reported that central defenders perform lower accelerations and decelerations than other playing positions. Another study (Oliva-Lozano et al., 2020) conducted a longitudinal study over 13 competitive microcycles recruiting professional footballers from LaLiga and detecting positional differences in terms of sprint, acceleration, and deceleration profiles. More specifically, greater start speeds than high-intensity accelerations were found in wide midfielders while no statistically significant differences could be reported in central defenders, full-backs, and midfielders. The high-intensity decelerations were performed by midfielders, forwards, full-backs, wide midfielders, and central defenders. Therefore, it seems that practitioners would adopt position-specific training programs that elicit higher acceleration/deceleration in outfielders.

Muscle damage markers, notably Ck, were higher in midfielders compared with defenders immediately and 24 h after the soccer match. Similar results have been reported in the existing scholarly literature with higher Ck immediately after the soccer match in midfielders than other playing positions (Souglis et al., 2018). These data could be explained by the fact that midfielders performed higher acceleration, deceleration, and explosive action than defenders. In contrast, another study (Scott et al., 2016) failed to stratify the Ck levels according to playing positions from 15 elite male soccer players competing in the English Premier League, 48 h following a competitive match. However, based on our findings, practitioners would adopt a position-specific recovery program after the soccer match to return to play as fast as possible.

LIMITATIONS AND STRENGTHS

Few studies have investigated Ck profiles in national team players (Hecksteden and Meyer, 2020; Schuth et al., 2021), generally adults (Hecksteden and Meyer, 2020) and more rarely adolescents (Schuth et al., 2021). The present investigation significantly adds to this literature.

However, despite this strength, the sample size is the main limitation of the study since the Strikers and Forwards groups are composed only of three and two individuals. Therefore, individual differences that may modify the outcome distributions of these groups more than the actual differences between groups could influence the ESs reported.

This study presents a further limitation that GPS/LPS substantially underestimated ∼4% of the criterion distance when striding and sprinting over short distances (10 m) at both 1 and 5 Hz (Jennings et al., 2010a,b). In contrast, we were able to control the interactions between the positions and the level and location of opponents. The interactions between the level and location of opponents and the positions were observed in total distance, load, and minutes of the game: in this study, international games presented more, i.e., ∼10% of total load and ∼900 m of total distance than the level of state games. This information could improve the periodization of players associated with international championships. However, despite this, these variables were not the determinant for Ck concentrations. Other limitations include the use of Ck as the only biomarker of muscle damage, while a wider array of biological parameters could have been explored. Further high-quality studies are needed to overcome these limitations.

CONCLUSION

Significant effects were observed in terms of the positions of the player when comparing performance indicators, as offensive midfielders had a higher total and relative distance and load during the high-level soccer games. The strikers had a lower percentage of submaximum, maximum, and up to maximum limit efforts during the game than other groups, while defenders demonstrated a higher frequency of sprints above 24 km/h. The forwards showed a higher number of jumps (<30 cm) and a total frequency of explosive efforts. Muscle damage (as assessed by means of Ck levels) did not differ in terms of playing position, suggesting a relevant muscle involvement for every player regardless of his position, up to 24 h after the match. More specifically, according to these findings, no training game format alone is able to develop the overall soccer fitness, with each format eliciting a unique physical load. These results make it possible to create a specific training game according to playing positions, associated with the predominant activities performed during competition. Consequently, practitioners would adopt a position-specific recovery program after the soccer match, particularly for midfielders who are exposed to higher muscle damage after the soccer match play.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by 13846919.8.000.5257/Hospital Universitário Clementino Fraga Filho-UFRJ. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LF, NE, and DG conceived the study, planned, carried out, and wrote the manuscript. MT, MS, HZ, NB, and BM performed the statistical analysis and reviewed the manuscript. MB realized the manuscript review and formatting. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

We would like to thank all athletes, coaches, and federations for allowing and contributing to the accomplishment of this study and also would like to thank the Taif University Researchers for Supporting Project (No. TURSP-2020/170), Taif University, Taif, Saudi Arabia.

REFERENCES

Abbott, W., Brickley, G., and Smeeton, N. J. (2018). Positional differences in GPS outputs and perceived exertion during soccer training games and competition. *J. Strength Cond. Res.* 32, 3222–3231. doi: 10.1519/JSC.0000000000002387

Ade, J., Fitzpatrick, J., and Bradley, P. S. (2016). High-intensity efforts in elite soccer matches and associated movement patterns, technical skills and tactical actions. Information for position-specific training drills. *J. Sports Sci.* 34, 2205–2214. doi: 10.1080/02640414.2016.1217343

Akubat, I., Barrett, S., Sagarra, M., and Abt, G. (2018). The validity of external:internal training load ratios in rested and fatigued soccer players. *Sports* 6:44. doi: 10.3390/sports6020044

Al Haddad, H., Simpson, B. M., Buchheit, M., Di Salvo, V., and Mendez-Villanueva, A. (2015). Peak match speed and maximal sprinting speed in young soccer players: effect of age and playing position. *Int. J. Sports Physiol. Perform.* 10, 888–896. doi: 10.1123/ijspp.2014-0539

Al'Hazzaa, H. M., Almuzaini, K. S., Al-Refaee, S. A., and Sulaiman, M. A. (2001). Aerobic and anaerobic power characteristics of Saudi elite soccer players. *J. Sports Med. Phys. Fitness* 41:54.

Anderson, L., Close, G. L., Morgans, R., Hambly, C., Speakman, J. R., Drust, B., et al. (2019). Assessment of energy expenditure of a professional goalkeeper from the english premier league using the doubly labeled water method. *Int. J. Sports Physiol. Perform.* 14, 681–684. doi: 10.1123/ijspp.2018-0520

Andrzejewski, M., Pluta, B., Konefa\l, M., Konarski, J., Chmura, J., and Chmura, P. (2019). Activity profile in elite polish soccer players. *Res. Sports Med.* 27, 473–484.

Andrzejewski, M., Pluta, B., and Posiadala, D. (2009). Characteristics of physical loads of young footballers during a championship match. *J. Hum. Kinet.* 21, 83–88.

Aquino, R., Martins, G. H. M., Vieira, L. H. P., and Menezes, R. P. (2017). Influence of match location, quality of opponents, and match status on movement patterns in Brazilian professional football players. *J. Strength Cond. Res.* 31, 2155–2161.

Aquino, R. L. Q. T., Gonçalvez, L. G. C., Vieira, L. H. P., Oliveira, L. P., Alvez, G. F., Santiago, P., et al. (2016). Periodization training focused on technical-tactical ability in young soccer players positively affects biochemical markers and game performance. *Strength Cond. Res.* 30, 2723–2732. doi: 10.1519/JSC.0000000000001381

Arjol-Serrano, J. L., Lampre, M., Díez, A., Castillo, D., Sanz-López, F., and Lozano, D. (2021). The influence of playing formation on physical demands and technical-tactical actions according to playing positions in an elite soccer team. *Int. J. Environ. Res. Pub. Health* 18:4148.

Brito, Â, Roriz, P., Silva, P., Duarte, R., and Garganta, J. (2017). Effects of pitch surface and playing position on external load activity profiles and technical demands of young soccer players in match play. *Int. J. Perform. Anal. Sport* 17, 902–918. doi: 10.1080/24748668.2017.1407207

Buchheit, M., Mendez-Villanueva, A., Simpson, B. M., and Bourdon, P. C. (2010). Match running performance and fitness in youth soccer. *Int. J. Sports Med.* 31, 818–825. doi: 10.1055/s-0030-1262838

Chmura, P., Konefał, M., Chmura, J., Kowalczuk, E., Zając, T., Rokita, A., et al. (2018). Match outcome and running performance in different intensityranges among elite soccer players. *Biol. Sport* 35, 197–203. doi: 10.5114/biolsport.2018.74196

Coppalle, S., Rave, G., Ben Abderrahman, A., Ali, A., Salhi, I., Zouita, S., et al. (2019). Relationship of pre-season training load with in-season biochemical markers, injuries and performance in professional soccer players. *Front. Physiol.* 10:409. doi: 10.3389/fphys.2019.00409

Dellal, A., Chamari, K., Wong, D. P., Ahmaidi, S., Keller, D., Barros, R., et al. (2011). Comparison of physical and technical performance in European soccer match-play: FA Premier league and La Liga. *Eur. J. Sport Sci.* 11, 51–59.

Dellal, A., Wong, D. P., Moalla, W., and Chamari, K. (2010). Physical and technical activity of soccer players in the French first league-with special reference to their playing position. *Int. SportMed J.* 11, 278–290.

Di Salvo, V., Baron, R., González-Haro, C., Gormasz, C., Pigozzi, F., and Bachl, N. (2010). Sprinting analysis of elite soccer players during European champions league and UEFA Cup matches. *J. Sports Sci.* 28, 1489–1494. doi: 10.1080/02640414.2010.521166

Djaoui, L., Wong, D. P., Pialoux, V., Hautier, C., Da Silva, C. D., Chamari, K., et al. (2013). Physical activity during a prolonged congested period in a top-class European football team. *Asian J. Sports Med.* 5, 47–53. doi: 10.5812/asjsm.34233

Enes, A., Oneda, G., Alves, D. L., Palumbo, D., de, P., Cruz, R., et al. (2021). Determinant factors of the match-based internal load in elite soccer players. *Res. Q. Exerc. Sport* 92, 63–70. doi: 10.1080/02701367.2019.1710445

Felipe, J. L., Garcia-Unanue, J., Viejo-Romero, D., Navandar, A., and Sánchez-Sánchez, J. (2019). Validation of a video-based performance analysis system (Mediacoach®) to Analyze the physical demands during matches in LaLiga. *Sensors* 19:4113. doi: 10.3390/s19194113

Gantois, P., Caputo Ferreira, M. E., Lima-Junior, D., Nakamura, F. Y., Batista, G. R., Fonseca, F. S., et al. (2020). Effects of mental fatigue on passing decision-making performance in professional soccer athletes. *Eur. J. Sport Sci.* 20, 534–543. doi: 10.1080/17461391.2019.1656781

Hecksteden, A., and Meyer, T. (2020). Blood-borne fatigue markers during major international football tournaments – a retrospective analysis of data from the FIFA World Championships and UEFA European Championships 2006 – 2016. *Sci. Med. Football* 4, 135–141. doi: 10.1080/24733938.2019.1692144

Hewitt, A., Norton, K., and Lyons, K. (2014). Movement profiles of elite women soccer players during international matches and the effect of opposition's team ranking. *J. Sports Sci.* 32, 1874–1880. doi: 10.1080/02640414.2014.898854

Izzo, R., and Varde'i, C. H. (2017). Differences by field positions between young and senior amateur soccer players using GPS technologies. *Ovidius Univ. Ann. Ser. Phys. Educ. Sport Sci. Mov. Health* 17, 344–353.

Jennings, D., Cormack, S., Coutts, A. J., Boyd, L., and Aughey, R. J. (2010a). The validity and reliability of GPS units for measuring distance in team sport specific running patterns. *Int. J. Sports Physiol. Perform.* 5, 328–341. doi: 10.1123/ijspp.5.3.328

Jennings, D., Cormack, S., Coutts, A. J., Boyd, L. J., and Aughey, R. J. (2010b). Variability of GPS units for measuring distance in team sport movements. *Int. J. Sports Physiol. Perform.* 5, 565–569. doi: 10.1123/ijspp.5.4.565

Mara, J. K., Thompson, K. G., Pumpa, K. L., and Ball, N. B. (2015). Periodization and physical performance in elite female soccer players. *Int. J. Sports Physiol. Perform.* 10, 664–669. doi: 10.1123/ijspp.2014-0345

Mendez-Villanueva, A., Buchheit, M., Simpson, B., and Bourdon, P. (2012). Match play intensity distribution in youth soccer. *Int. J. Sports Med.* 34, 101–110. doi: 10.1055/s-0032-1306323

Milanović, Z., Rađa, A., Erceg, M., Trajković, N., Stojanović, E., Lešnik, B., et al. (2020). Reproducibility of internal and external training load during recreational small-sided football games. *Res. Q. Exerc. Sport* 91, 676–681. doi: 10.1080/02701367.2019.1697794

Modric, T., Versic, S., Sekulic, D., and Liposek, S. (2019). Analysis of the association between running performance and game performance indicators in professional soccer players. *Int. J. Environ. Res. Pub. Health* 16:4032. doi: 10.3390/ijerph16204032

Mohr, M., Krustrup, P., and Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *J. Sports Sci.* 21, 519–528. doi: 10.1080/0264041031000071182

Oliva-Lozano, J. M., Fortes, V., Krustrup, P., and Muyor, J. M. (2020). Acceleration and sprint profiles of professional male football players in relation to playing position. *PLoS One* 15:e0236959. doi: 10.1371/journal.pone.0236959

Oliveira, R., Brito, J., Martins, A., Mendes, B., Calvete, F., Carriço, S., et al. (2019). In-season training load quantification of one–, two- and three-game week schedules in a top European professional soccer team. *Physiol. Behav.* 201, 146–156. doi: 10.1016/j.physbeh.2018.11.036

Petersen, C., Pyne, D., Portus, M., and Dawson, B. (2009a). Validity and reliability of GPS units to monitor cricket-specific movement patterns. *Int. J. Sports Physiol. Perform.* 4, 381–393. doi: 10.1123/ijspp.4.3.381

Petersen, C., Pyne, D. B., Portus, M. R., Karppinen, S., and Dawson, B. (2009b). Variability in movement patterns during one day internationals by a cricket fast bowler. *Int. J. Sports Physiol. Perform.* 4, 278–281. doi: 10.1123/ijspp.4.2.278

Rampinini, E., Impellizzeri, F. M., Castagna, C., Azzalin, A., Bravo, D. F., and Wisløff, U. (2008). Effect of match-related fatigue on short-passing ability in young soccer players. *Med. Sci. Sports Exerc.* 40, 934–942. doi: 10.1249/MSS.0b013e3181666eb8

Reinhardt, L., Schwesig, R., Lauenroth, A., Schulze, S., and Kurz, E. (2019). Enhanced sprint performance analysis in soccer: new insights from a GPS-based tracking system. *PLoS One* 14:e0217782. doi: 10.1371/journal.pone.0217782

Russell, M., Sparkes, W., Northeast, J., Cook, C. J., Bracken, R. M., and Kilduff, L. P. (2016). Relationships between match activities and peak power output and creatine kinase responses to professional reserve team soccer match-play. *Hum. Mov. Sci.* 45, 96–101. doi: 10.1016/j.humov.2015.11.011

Sarmento, H., Catita, L., and Fonseca, A. (2008). "Sport motivation–A comparison between adult football players competing at different levels," in *Proceedings of the 5th International Scientific Conference on Kinesiology*, Zagreb.

Sarmento, H., Clemente, F. M., Araújo, D., Davids, K., McRobert, A., and Figueiredo, A. (2018). What performance analysts need to know about research trends in association football (2012–2016): a systematic review. *Sports Med.* 48, 799–836. doi: 10.1007/s40279-017-0836-6

Schuth, G., Szigeti, G., Dobreff, G., Revisnyei, P., Pasic, A., Toka, L., et al. (2021). Factors influencing creatine kinase response in youth national team soccer players. *Sports Health* 13, 332–340. doi: 10.1177/1941738121999387

Scott, A., Malone, J. J., Morgans, R., Burgess, D., Gregson, W., Morton, J. P., et al. (2016). The relationship between physical match performance and 48-h post-game creatine kinase concentrations in English Premier League soccer players. *Int. J. Sports Sci. Coach.* 11, 846–852. doi: 10.1177/1747954116676111

Silva, J. R., Rumpf, M. C., Hertzog, M., Castagna, C., Farooq, A., Girard, O., et al. (2018). Acute and residual soccer match-related fatigue: a systematic review and meta-analysis. *Sports Med.* 48, 539–583. doi: 10.1007/s40279-017-0798-8

Slimani, M., and Nikolaidis, P. T. (2019). Anthropometric and physiological characteristics of male soccer players according to their competitive level, playing position and age group: a systematic review. *J. Sports Med. Phys. Fitness* 59, 141–163.

Slimani, M., Znazen, H., Miarka, B., and Bragazzi, N. L. (2019). Maximum oxygen uptake of male soccer players according to their competitive level, playing position and age group: implication from a network meta-analysis. *J. Hum. Kinet.* 66:233.

Souglis, A., Bogdanis, G. C., Chryssanthopoulos, C., Apostolidis, N., and Geladas, N. D. (2018). Time course of oxidative stress, inflammation, and muscle damage markers for 5 days after a soccer match: effects of sex and playing position. *J. Strength Cond. Res.* 32, 2045–2054. doi: 10.1519/JSC.0000000000002436

Strauss, A., Sparks, M., and Pienaar, C. (2019). The use of GPS analysis to quantify the internal and external match demands of semi-elite level female soccer players during a tournament. *J. Sports Sci. Med.* 18, 73–81.

Varley, M. C., Gregson, W., McMillan, K., Bonanno, D., Stafford, K., Modonutti, M., et al. (2017). Physical and technical performance of elite youth soccer players during international tournaments: influence of playing position and team success and opponent quality. *Sci. Med. Football* 1, 18–29. doi: 10.1080/02640414.2016.1230676

Vescovi, J. D., and Favero, T. G. (2014). Motion Characteristics of women's college soccer matches: female athletes in motion (FAiM) study. *Int. J. Sports Physiol. Perform.* 9, 405–414. doi: 10.1123/ijspp.2013-0526

Vigne, G., Gaudino, C., Rogowski, I., Alloatti, G., and Hautier, C. (2010). Activity profile in elite italian soccer team. *Int. J. Sports Med.* 31, 304–310. doi: 10.1055/s-0030-1248320

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Psychology

ORIGINAL RESEARCH
published: 20 September 2021
doi: 10.3389/fpsyg.2021.724070

Kinematic and Neuromuscular Measures of Intensity During Drop Jumps in Female Volleyball Players

Maximiliano Torres-Banduc[1,2], Rodrigo Ramirez-Campillo[3], David Cristobal Andrade[4], Julio Calleja-González[5], Pantelis Theo Nikolaidis[6], John J. McMahon[7] and Paul Comfort[7,8,9]*

[1] Escuela de Kinesiología, Facultad de Ciencias de la Salud, Universidad de Las Américas, Viña del Mar, Chile, [2] Escuela de Ciencias de la Salud, Universidad de Viña del Mar, Viña del Mar, Chile, [3] Department of Physical Activity Sciences, Universidad de Los Lagos, Osorno, Chile, [4] Centro de Investigación en Fisiología y Medicina de Altura, Faculty of Health Science, Universidad de Antofagasta, Antofagasta, Chile, [5] Department of Physical Education and Sport, Faculty of Education and Sport, University of the Basque Country, Vitoria-Gasteiz, Spain, [6] Exercise Physiology Laboratory, Nikaia, Greece, [7] Directorate of Psychology and Sport, School of Health and Society, University of Salford, Salford, United Kingdom, [8] Institute for Sport, Physical Activity and Leisure, Carnegie School of Sport, Leeds Beckett University, Leeds, United Kingdom, [9] Centre for Exercise and Sports Science Research, Edith Cowan University, Joondalup, WA, Australia

OPEN ACCESS

Edited by:
Bernard J. Martin,
University of Michigan, United States

Reviewed by:
Maria Gabriela Garcia,
Universidad San Francisco de Quito, Ecuador
Janet S. Dufek,
University of Nevada, Las Vegas, United States

***Correspondence:**
Rodrigo Ramirez-Campillo
r.ramirez@ulagos.cl

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: 11 June 2021
Accepted: 27 August 2021
Published: 20 September 2021

Citation:
Torres-Banduc M, Ramirez-Campillo R, Andrade DC, Calleja-González J, Nikolaidis PT, McMahon JJ and Comfort P (2021) Kinematic and Neuromuscular Measures of Intensity During Drop Jumps in Female Volleyball Players. Front. Psychol. 12:724070. doi: 10.3389/fpsyg.2021.724070

The aim of this study was to assess drop jump (DJ) performance variables (jump height, contact time, and reactive strength index) concomitant to surface electromyography (sEMG) of lower limb muscles during DJs from different drop heights (intensities). The eccentric and concentric phase sEMG from the gastrocnemius medialis, biceps femoris, and vastus medialis muscles were assessed during all tests, with sEMG activity normalized to maximal voluntary isometric contraction (MVIC). In a cross-sectional, study, 10 amateur female volleyball players (age 22.1 ± 1.8 years; body mass 72.9 ± 15.2 kg; height 1.70 ± 0.08 m) completed DJs from six heights [15–90 cm (DJ15 to DJ90)]. During DJs there was no jump-target box to rebound on to. Results of one-way analysis of variance (ANOVA) showed that the jump height, contact time, and reactive strength index were not significantly ($p > 0.05$) different between drop heights. Mean biceps femoris eccentric and concentric sEMG ranged from 27 to 50%, although without significant differences between drop heights. Mean gastrocnemius medialis eccentric and concentric sEMG remained relatively constant (~60–80% MVIC) across DJs heights, although eccentric values reached 90–120% MVIC from DJ75 to DJ90. Mean variations of ~50–100% MVIC for eccentric and ~50–70% MVIC for concentric sEMG activations were observed in the vastus medialis across DJs heights. The biceps femoris eccentric/concentric sEMG ratio during DJ45 (i.e., 1.0) was lower ($p = 0.03$) compared to the ratio observed after DJ90 (i.e., 3.2). The gastrocnemius medialis and vastus medialis eccentric/concentric sEMG ratio were not significantly different between drop heights. In conclusion, jumping performance and most neuromuscular markers were not sensitive to DJ height (intensity) in amateur female volleyball athletes.

Keywords: volleyball, team sport, sports, human physical conditioning, resistance training, plyometric exercise, muscle contraction, electromyography

INTRODUCTION

Volleyball is a team sport characterized by periods of short duration (i.e., 3–9 s), high-intensity activities, interspersed with periods (i.e., 10–20 s) of recovery (García-De-Alcaraz et al., 2020). Although the actions performed by players may vary in terms of their individual roles, related to technical and tactical requirements, accelerations, decelerations, jumping, ball-striking, and multidirectional locomotion are common movements (Sheppard et al., 2007). In particular, jumping ability has previously been shown to be related to better performance in volleyball (Ziv and Lidor, 2010). In fact, scoring actions (i.e., spike, block, and serve) are mainly performed while jumping vertically (Sheppard et al., 2007). Indeed, there is a significant increase in the number of jumps per set (113.5–181.3 jumps), from young to elite players in men's volleyball (De Alcaraz et al., 2017). Accordingly, with the principle of training specificity volleyball players should systematically engage in jump-related training programs to improve sports performance (Gabbett, 2016), in a phased, sequential, manner which also includes the development of maximal force production characteristics (i.e., strength) (Lloyd et al., 2011).

Plyometric exercises are often used in jump-related training programs to improve jumping ability, which play a pivotal role in volleyball performance (Ziv and Lidor, 2010). In fact, volleyball is considered a very "explosive" and fast-paced sport in which plyometric training is widely used (Silva et al., 2019). The drop jump (DJ) is a common plyometric drill, especially among volleyball players (Ziv and Lidor, 2010; Silva et al., 2019) and comprises of a rapid transition between the eccentric-concentric [i.e., stretch-shortening cycle (SSC)] muscle actions (Heiderscheit et al., 1996), allowing greater muscle activation and force *via* stimulation of the muscle spindle (Peng et al., 2011). The alternating eccentric-concentric muscle work also leads to the accumulation of potential elastic energy (*via* the series and parallel elastic components), consequently allowing more work to be performed in the concentric phase (Taube et al., 2012). However, optimal drop height when performing DJs to promote muscle performance is inconclusive (Ramirez-Campillo et al., 2013), especially regarding DJ intensity.

Commonly, athletes perform DJs at increased heights for a greater training intensity stimulus (Peng et al., 2011), as a greater drop height results in an increased duration for acceleration, leading to an increased velocity of the center of mass and therefore an increased momentum on impact with the ground. In this sense, it has been suggested that intensity could be evaluated by examining a variety of kinematic parameters (e.g., jump height) and by assessing the activation of muscle by surface electromyography (sEMG) (Ebben et al., 2008). In practical terms, acute increases in sEMG during training exercises may lead to greater training-related adaptations, as suggested in previous studies with team-sport athletes (Serner et al., 2014). However, the interpretation of this must be done with caution considering there is no simple closed-form or equation that describes this relationship (Disselhorst-Klug and Williams, 2020). The sEMG is commonly used as a marker of intensity in strength training exercise (Krommes et al., 2017), with a quadratic increase in root-mean-square amplitude of the sEMG signal across force levels from 20, 40, 60, 80, and 100% of maximal voluntary contraction (Lenhardt et al., 2009). Moreover, greater intensity usually allow greater training-related adaptations (ACSM, 2009). Regarding DJs, it has been shown that greater drop heights may have a significant effect on sEMG achieved during the rebound jump (Aboodarda et al., 2014), with greater sEMG activity during DJs executed from a 60 cm box (DJ60) than from a 40 cm (DJ40) (Bobbert et al., 1987b) or 20 cm box (DJ20) (Peng et al., 2011), suggesting greater plyometric jump intensity from greater drop heights. Similarly, the use of DJ height that allow athletes to achieve maximal reactive strength index may offer greater training-induced adaptations (Ramirez-Campillo et al., 2018b). In this sense, outcomes such as reactive strength index or sEMG can be used as a proxy for potential adaptations. However, not all studies agree with these assertions (Ebben et al., 2008). Moreover, although power output and reactive strength may augment with initial increases in box drop height, if drop height continues to increase the overall muscle performance may be negatively affected (Flanagan and Comyns, 2008), if the athlete does not possess the appropriate force production capabilities required to rapidly decelerate and accelerate their center of mass. Indeed, such relationships may be modulated by athlete's characteristics, such as the sex of the athlete and their relative strength capabilities, the latter being particularly relevant among females, including female volleyball players (Beckham et al., 2019; Fuchs et al., 2019).

Although some researchers have assessed kinematic and neuromuscular measures of intensity during SSC actions (Ebben et al., 2008; Ebben et al., 2011), whether the results from such studies are replicable in volleyball players is a matter of further research. Previously, jumping performance and neuromuscular markers (Andrade et al., 2020), as well as biomechanical outcomes (Peng et al., 2019) in male volleyball players, were sensitive to DJ height, although not in a clear dose-response fashion. Regarding female volleyball players, the lack of studies preclude analysis of such phenomenon, although it seems that important differences between male and female volleyball players may be hypothesized (Fuchs et al., 2019). Considering the lack of plyometric training studies conducted among females compared to males (Ramirez-Campillo et al., 2018a) and the increased participation of females in volleyball, particularly at amateur level, more research on this issue is needed. This may help strength and conditioning coaches to prescribe adequate plyometric training loads, as needless extra training (e.g., excessive DJ heights) may expose athletes to greater injury risk, especially among females (Brumitt et al., 2016).

From a biomechanical standpoint as the increased drop height results in increased drop duration and therefore acceleration, this would result in a higher impact velocity, increased momentum, and so a higher braking net impulse (Bobbert et al., 1987a). Due to the aforementioned biomechanical considerations, increased drop heights may impose a suboptimal intensity-related stimulus if the athlete does not possess the appropriate force production capabilities required to rapidly decelerate and accelerate their center of mass. Even among male volleyball players, whom usually have greater strength level compared to females, increased drop height may not be an appropriate intensity-related stimulus (Andrade et al., 2020). Moreover, although reactive strength index and jump height may augment with initial increases in box drop height, further drop height increases are expected to reduce reactive strength index and jump height (Flanagan and Comyns, 2008). Therefore, the main aim of this study was to assess maximal jumping performance and neuromuscular activity in lower limb muscles of amateur female volleyball players after DJ from different drop heights, using markers such as reactive strength index, jump height, contact time, and sEMG. We hypothesized that increasing the drop height during DJ will induce greater contact time among amateur female volleyball players, with greater sEMG, although reduced reactive strength index and jump height.

MATERIALS AND METHODS

Experimental Approach to the Study

This study followed a cross-sectional design. Female volleyball players were assessed for the effects of box height during DJ on sEMG, reactive strength index, jump height, and contact time. Jumps were completed from 15-, 30-, 45-, 60-, 75-, and 90 cm boxes.

Participants

Ten female amateur volleyball players (age, 22.1 ± 1.8 years; body mass, 72.9 ± 15.2 kg; height, 1.70 ± 0.08 m; body mass index, 25.1 ± 4.2 kg/m2) participated in this study. The participants positions were as follow: middle-blocker (n = 2), libero (n = 1), spiker (n = 5), and opposite-spiker (n = 2). Athletes were recruited during the competitive period, where they usually completed one regional-level competition per week. Athletes participated in regular volleyball training sessions for 2 h per day, 3 days per week, during 3 months prior to inclusion in this study. All athletes had ≥2 years of regular training and competition experience in volleyball. At recruitment in this study, most of the volleyball training practice was devoted to technical and tactical drills. Moreover, the participants had no regular experience with resistance training or structured plyometric training in the 3 months preceding this study, particularly with DJs. Inclusion criteria were: (i) healthy by self-report (heart and pulmonary disease, and recent surgeries); (ii) completion of an exhaustive health questionnaire; (iii) without injury history in the past 3 months prior to testing (confirmed by checking their training logs with the team head coach). Exclusion criteria were: (i) any condition considered to affect muscle function (e.g., recent bone fractures) or the measurement protocol (e.g., herniated discs); and (ii) being on medications considered to affect dependent variables (e.g., anabolic steroids). The methods and procedures used were approved by the local university (CODE: N°155/2018-code 195.18) and were based on the latest version of the Helsinki declaration.

Data Collection

To increase testing reliability and minimize learning effects, participants were familiarized with testing protocols during two 1-h sessions, the week before measurements. During familiarization, participants completed a maximal voluntary isometric contraction (MVIC) test on day one and a series of DJ tests on the next familiarization session, with ≥48 h from previous MVIC testing. During testing sessions, the participants performed the MVIC and (after 5 min of recovery) DJs on the same day (avoiding repositioning of the electrodes). The day before a testing session, participants were instructed to perform a low-intensity workout and maintain their dietary routine. A standardized warm-up was completed before each testing session including 5 min of free running and 5 min of dynamic jumps and dynamic stretching (Andrade et al., 2015). All jump tests were performed on the volleyball court where the participants trained and competed. Participants were asked to use the same sport garments, including the shoes that they usually wore during training and/or competition. The sEMG activity was recorded during each test. All measurements were conducted on the same laboratory, under controlled temperature and humidity conditions. Although we did not control for hormone status nor menstrual cycle phase, all the participants were eumenorrheic and did not take any hormonal contraceptive. Furthermore, previous works did not find differences in the DJ (Sipavičiené et al., 2013) performance over the course of an ovarian menstrual cycle. All tests were conducted and at the same time of day to avoid the influence of circadian rhythms.

Anthropometry

Standing height (m) and body mass (kg) were assessed using a stadiometer/mechanical scale (SECA, model 220, Hamburg, Germany) with precisions of 0.1 cm and 0.1 kg, respectively. Subjects were tested in light clothing (shoes were removed). The body mass index was calculated from the two measurements ($kg \cdot m^{-2}$).

Maximal Voluntary Isometric Contraction

Following a thorough explanation of the testing procedures, the athletes completed a specific warm-up by completing several submaximal contractions of the knee extensor and plantar flexor musculature. After the warm-up, athletes completed three knee and ankle extension and flexion non-ramped MVIC trials on an isokinetic dynamometer (Biodex®, System 3 Pro, NY, United States) (see **Figure 1A**), with 1 min resting among trials (Ebben et al., 2010). For all MVIC attempts, the gravity effect torque was obtained by weighing the limb with the isokinetic device, and the participants were instructed to perform at maximal effort, given them the instruction to "try to extend your leg (or foot), as hard as you can." Verbal encouragement was provided during maximal attempts. Each MVIC trial lasted 4–5 s. During the knee extension test, the participants seated in the dynamometer so that their hip and knee joints were positioned at ∼90° angles. Strap was wrapped ∼3 cm above the lateral malleolus of the athlete's ankle (dominant side), as well as at the thigh, waist, and chest. Care was taken to align the centers of rotation of the knee joint and dynamometer. In the ankle flexion MVIC test, the dynamometer orientation was set at 90°, with a tilt at 0°, seat orientation at 90°, seatback tilt at 70–85°, footplate tilt at 0°, and knee flexion at 20–30°. The axis of rotation was set in neutral position, were axis passes through the body of talus, fibular malleolus, and through or just below the tibial malleolus. The dominant ankle of the athlete (determined by asking the participant the preferred leg used to kick a ball) was attached to the dynamometer with an ankle attachment device, in addition to the use of straps at the chest and waist.

Drop Jump Tests

Drop jump heights were randomly selected from 15-, 30-, 45-, 60-, 75-, and 90 cm boxes (DJ15, DJ30, DJ45, DJ60, DJ75, and DJ90, respectively) (see **Figure 1A**), and participants completed 3 trials at each randomly selected height. An electronic contact mat (Axon Jump 4.0, Bioengineering Sports, Argentina) (see **Figure 1B**) was used to measure contact time (ms) and flight time, the latter of which was used to calculate jump height. Besides, the reactive strength index was calculated as jump height/contact time ($mm{\cdot}ms^{-1}$), as previously described (Flanagan and Comyns, 2008). Players jumped with arms akimbo and stepped of the box with the leading leg straight to avoid any initial upward propulsion during DJ execution. Upon landing, they were instructed to jump for maximal height and minimal contact time in order to maximize reactive strength index (Barnes et al., 2007). They had 30 s of rest between jumps and 60 s between heights (Andrade et al., 2020). Of note, each athlete completed 18 total jumps (i.e., 3 trials × 6 box heights). Maximal performance (e.g., jump height) was most commonly achieved during the first or second trial (i.e., in 36 of 60 maximal jumps), suggesting lack of learning effect from repeated trials. Additionally, pilot statistical analyses indicated that the mean or the best value (from 3 trials) yielded similar results (i.e., outcomes $p > 0.05$ between DJ heights). Considering that maximal jumping performance may be more ecologically valid for volleyball players, the best performance trial (higher reactive strength index value, associated jump height, and contact time) was used for statistical analysis as previously suggested (Andrade et al., 2020).

Surface Electromyography

The sEMG data was acquired (Trigno Wireless System, Delsys, Natick, MA, United States) and used to quantify muscle activity. After warm-up the skin was carefully shaved, abraded and cleansed with alcohol prior to application of EMG + IMU sensor (Trigno Avanti Sensor, Delsys, Natick, MA, United States), whose sample rate of the EMG signal is 1950 and 148 Hz for the accelerometer. As previously suggested (Andrade et al., 2020) the electrodes were placed on the muscle belly surface of the biceps femoris, gastrocnemius medialis and vastus medialis muscles of the dominant leg according to the "Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM)" recommendations.[1] The electrodes were secured with adhesive tape (3M, Canada). The sEMG signals from each electrode were amplified (input impedance 120 kΩ; signal to noise ratio 750; inter-electrode distance of 10 mm) (Ebben et al., 2008) and gain range of 500–5000. Surface electrodes were connected by Wi-Fi to a base station (Trigno Base Station, Trigno Wireless System, Delsys, Natick, MA, United States) and streamed continuously to a computer through an analog to digital converter (G-42, HP notebook computer, United States). The sEMG data was managed with computer software (EMGworks®, Delsys, Natick, MA, United States). All data were centered and filtered with a 10 Hz high-pass and a 500 Hz low-pass second order infinite impulse response (IIR) Butterworth filter.

Surface electromyography and IMU data recording

The root mean square (RMS) was used to assess sEMG recorded during jump testing (Ebben et al., 2008). Data were calculated using a 60 ms moving window. Data were analyzed to identify the pre- and post-contact muscle burst timing and the magnitude of action for the jump (Ebben et al., 2010). The RMS was evaluated as previously suggested (Gonzalez-Izal et al., 2012):

$$RMS = \sqrt{\frac{1}{n}\sum_{n} x_n^2}$$

where Xn is the value of the sEMG signal and n is the sample number. During DJ the eccentric and concentric sEMG activity was recorded, coupled with an inertial measurement unit to detect each phase (Trigno Avanti EMG + IMU Sensor, Delsys, Natick, MA, United States). To this aim, the IMU was placed at 1/3 on the line between the tip of the fibula and the tip of the medial malleolus. Behavior analysis of the IMU acceleration signal during a DJ was conducted in a pilot session before the testing sessions. After the application of 10 Hz finite-impulse-response (FIR) filter, signal rectification, and low-pass filtered with a 5 Hz FIR filter, both using a Blackman window (i.e., acceleration impact filter), an initial peak at the beginning of the DJ was noted, corresponding to initial DJ ground contact (start of the eccentric phase), visually determined as the increase in the amplitude of the acceleration (above baseline). Thereafter, the peak progressively descended until return to baseline (i.e., end of the initial peak, end of the eccentric phase, and start of the concentric phase). Another peak was observed after the flight phase of the DJ. Using data from contact time and flight time, calculations allowed the identification of the eccentric and concentric phases. From these recordings, eccentric/concentric ratio was calculated. Each RMS sEMG data was expressed as a percentage of MVIC (Walker et al., 2012) using the highest sEMG recorded during MVIC trials (Andrade et al., 2020). The reliability of these measures has previously been established (Gonzalez-Izal et al., 2012).

Statistical Analyses

The data used in the statistical analyses is available from the corresponding author upon reasonable request.

The Shapiro–Wilk ($n < 50$) and Levene tests, respectively analyzed the normality and homoscedasticity of the outcome variables. When the data did not confront to the test for normality and/or homogeneity of variance, they were log transformed and were back transformed for presentation purposes.

Data are presented as mean ± SEM. The within-session (between-trial) reliabilities of all dependent variables were assessed by calculating intra-class correlation coefficients and

[1] http://www.seniam.org

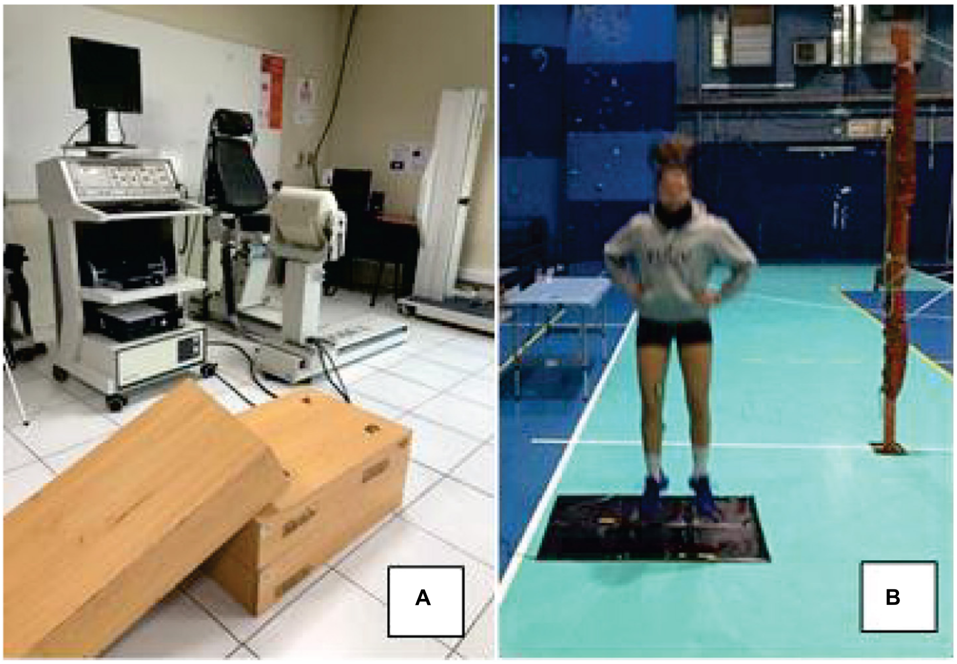


FIGURE 1 | Setup used to evaluate the participants in the study. **(A)** Isokinetic for maximal voluntary isometric contraction and boxes (i.e., 15 cm height each) used during drop jumps and **(B)** contact mat, with participant warming up before measurements.

coefficient of variation and the associated 95% confidence intervals. As previously suggested, intra-class correlation coefficients values <0.5, between 0.5 and 0.75, between 0.75 and 0.9, and >0.9 were interpreted as poor, moderate, good, and excellent reliability, respectively, based on the lower bound 95% confidence interval (Koo and Li, 2016).

To calculate the sample size, validated (Faul et al., 2007) statistical software (GPower; University of Dusseldorf, Dusseldorf, Germany) was used. Given the study design (one groups and six repeated measures), a moderate effect size (Cohen's f) = 0.6–1.2 (Andrade et al., 2020), alpha-error < 0.05, the non-sphericity correction € = 1, the correlation between the repeated measures = 0.5, and a desired power (1-β error) = 0.95, the total sample size resulted in six participants. Considering potential dropouts, the minimal initial sample size was set at 10 participants. Considering the characteristics of the sample (i.e., females; amateur level) and the test [i.e., very short duration (<1 s per trial)], a reliability threshold was set at ≤10% for the coefficient of variation (Stokes, 1985).

A series of repeated measures one-way ANOVA tests were used to compare dependent variables collected during the DJ. When a significant F-value was achieved, Bonferroni *post hoc* procedures were performed to locate the pairwise differences between the means. Effect sizes (ES) were determined by calculating partial eta-squared (η_p^2) derived from ANOVA analysis, converted to Cohen's d values as previously outlined (Fritz et al., 2012) and interpreted using the conventions outlined for sport sciences: <0.2, trivial; 0.2–0.6, small; >0.6–1.2, moderate; >1.2–2.0, large; >2.0–4.0, very large; >4.0, extremely large (Hopkins et al., 2009). Significance was set at an *a priori* alpha level of $p < 0.05$. All statistical calculations were performed using STATISTICA® Software (Version 8.0, StatSoft, Inc., Tulsa, OK, United States).

RESULTS

For the DJ performance variables contact time, jump height, and reactive strength index, the intra-class coefficients were calculated, for each of the six drop heights, yielding 18 calculations, and 8 demonstrated good reliability, 7 moderate reliability, and 3 poor reliability, based on the lower bound 95% confidence intervals for intra-class correlation coefficients (**Table 1**). The general trend was for reliability to reduce with an increase in drop height. Regarding the coefficient of variation, 12 out of 18 calculations achieved the ≤10% threshold, with a general trend for reduced reliability in the reactive strength index.

The lowest contact time was achieved in the DJ30 (375.2 ± 41.7 ms), and the highest was achieved in the DJ90 (460.6 ± 50.0 ms), with a difference of ∼23%, although no significant (i.e., trivial) differences were observed between drop heights (**Table 2**). Furthermore, the jump height of the athletes ranged from 27.7 to 29.3 cm, and from 0.66 to 0.87 $mm \cdot ms^{-1}$ for reactive strength index, without significant differences between any drop heights (**Table 2**).

The sEMG of the biceps femoris during the eccentric phase varied from 32% (DJ75) to 50% (DJ90), although without significant differences between any drop heights (**Table 2**). Similarly, the biceps femoris concentric sEMG activation varied between 27 and 42%, without significant differences between

TABLE 1 | Reliability [intra-class correlation coefficient (ICC) and coefficient of variation (CV)] of drop jump performance variables.[1]

	DJ15	DJ30	DJ45	DJ60	DJ75	DJ90
Contact time						
ICC	0.95 (0.82–0.99)	0.96 (0.84–0.99)	0.96 (0.84–0.99)	0.91 (0.69–0.98)	0.97 (0.87–0.99)	0.86 (0.38–0.97)
CV	8.8% (6.0–16.6%)	9.3% (6.3–17.6%)	9.2% (6.3–17.5%)	11.8% (8.0–22.6%)	6.2% (4.1–12.2%)	9.6% (6.1–22.3%)
Jump height						
ICC	0.96 (0.84–0.99)	0.92 (0.71–0.98)	0.91 (0.67–0.98)	0.94 (0.76–0.98)	0.87 (0.53–0.97)	0.92 (0.60–0.99)
CV	4.9% (3.3–9.0%)	4.4% (3.4–9.2%)	6.0% (4.1–11.2%)	4.8% (3.2–8.9%)	8.7% (5.8–17.4%)	8.4% (5.3–19.4%)
Reactive strength index						
ICC	0.93 (0.76–0.98)	0.93 (0.72–0.98)	0.93 (0.75–0.98)	0.93 (0.73–0.98)	0.82 (0.40–0.96)	0.80 (0.20–0.96)
CV	11.2% (7.6–21.4%)	11.7% (8.6–24.3%)	12.3% (8.3–23.5%)	11.2% (7.6–21.3%)	13.6% (9.0–27.8%)	9.4% (6.0–21.9%)

[1]*Values in parenthesis include 95% confidence intervals.*

any drop heights (**Table 2**). Similarly, gastrocnemius medialis eccentric sEMG activation remained relatively constant between DJ15 and DJ60 (∼60–70%), with an increase up to 117% in DJ90, although these were not significant between drop heights (**Table 2**). For the gastrocnemius medialis concentric sEMG, no significant differences were observed between any drop heights, with activation varying between 63 and 76% (**Table 2**). The vastus medialis eccentric sEMG, although initially showed a reduction from DJ15 (∼69%) to DJ30 (∼55%), thereafter a relatively constant increase was noted up to a maximum of 104% achieved after DJ90 (**Table 2**), although these were not significant (**Table 2**). The vastus medialis concentric sEMG highlighted no significant variation (52–72%) between drop heights (**Table 2**).

The biceps femoris eccentric to concentric sEMG ratio was relatively constant between DJ15 to DJ75, however, compared to the ratio achieved after DJ45 (i.e., 1.0), a significant (p = 0.03; $\eta_p^2 = 0.21$; d = 1.0, moderate) greater ratio was observed after DJ90 (i.e., 3.2) (**Figures 2A,B**). The gastrocnemius medialis eccentric to concentric sEMG ratio showed a reduction from DJ15 (i.e., 1.5) to DJ45 (i.e., 0.9), and thereafter a relatively constant increase up to DJ90 (i.e., 1.7), although without significant differences between drop heights (**Table 2**). The vastus medialis eccentric to concentric sEMG ratio showed variations between 1.0 (DJ30) and 2.5 (DJ90), although without significant differences between drop heights (**Table 2**).

DISCUSSION

The main aim of this study was to assess jumping performance and neuromuscular activity in lower limb muscles of female volleyball athletes after DJ from different drop heights, using parameters such as reactive strength index, jump height, contact time, and sEMG. Based on a previous study (Andrade et al., 2020), we hypothesized that increasing the drop height during DJ will not ensure greater kinematic and neuromuscular measures of intensity during plyometric jumps in female volleyball players. Indeed, aside from a greater biceps femoris eccentric/concentric sEMG ratio after DJ90 compared to DJ45, no significant differences were noted between drop heights for the outcomes analyzed in female volleyball players. Therefore, jumping performance and neuromuscular markers were not sensitive to DJ height within these amateur female volleyball athletes.

No significant differences in contact time were noted between DJ15 to DJ90 box heights, whereas a ∼23% increase (although no significant) in contact time was noted in the DJ90 compared to previous drop heights. Relatedly, the reactive strength index, although did not varied significantly across the different drop heights, the lowest value (i.e., 0.7) was achieved after DJ90, a ∼22% reduction compared to the highest reactive strength index value achieved in the DJ30 (i.e., 0.9). Such reduction almost perfectly mimics the increase in the contact time observed in the DJ90. Athletes commonly perform DJs at increased heights for a greater training-intensity stimulus (Peng et al., 2011), with some studies showing greater sEMG activity after DJs executed from a 60 cm box (DJ60) than from a 40 cm (DJ40; i.e., males) (Bobbert et al., 1987b) or 20 cm box (DJ20; i.e., males and females) (Peng et al., 2011). Although this may suggest greater plyometric jump intensity from greater drop heights, our results, in contrast suggest that neither greater sEMG occurred nor greater kinematic (i.e., jump height, reactive strength index, and contact time) performance. Differences between the results of previous studies and our results are not easy to explain. However, participant's sex seems not a key factor, as previous studies in male volleyball players also found that increasing the drop height during DJs does not ensure a greater training intensity (Andrade et al., 2020). Moreover, similar to our findings, some studies also have noted that greater DJ height may, in fact, reduce performance (i.e., reactive strength index and jump height), for both trained and untrained participants (Flanagan and Comyns, 2008). Therefore, using greater drop height may not always be an efficient strategy to increase training intensity for female volleyball players, as an important reduction in reactive strength index development may be induced, and a suboptimal reactive strength index during training may limit maximization of training-induced adaptations (Ramirez-Campillo et al., 2018b). Moreover, a greater drop height box could increase vertical ground reaction forces (vGRF) (Jensen and Ebben, 2007; Ebben et al., 2008, 2011). Even a

TABLE 2 | Comparison of drop jump performance variables and surface electromyography (%MVC) between drop heights.

	DJ15	DJ30	DJ45	DJ60	DJ75	DJ90	ANOVA outcomes Group F(5, 50), p-value (η_p^2)
Contact time (ms)	384.8 ± 34.2	375.2 ± 41.7	392.8 ± 45.9	377.6 ± 39.5	383.1 ± 34.9	**460.6 ± 50.0**	$F = 0.5, p = 0.78$ (0.05)
Jump height (cm)	27.7 ± 1.8	**29.3 ± 1.6**	29.2 ± 1.5	27.8 ± 1.4	29.0 ± 1.5	28.8 ± 1.6	$F = 0.2, p = 0.96$ (0.02)
Reactive strength (mm.ms^{-1})	0.76 ± 0.01	**0.87 ± 0.10**	0.84 ± 0.11	0.80 ± 0.08	0.80 ± 0.07	0.66 ± 0.07	$F = 0.7, p = 0.66$ (0.06)
BF EC (%MVC)	39.3 ± 9.3	37.0 ± 8.9	37.7 ± 11.0	42.5 ± 11.0	31.6 ± 4.5	**50.0 ± 16.2**	$F = 0.3, p = 0.92$ (0.03)
BF CON (%MVC)	28.6 ± 6.8	30.0 ± 7.1	36.0 ± 7.6	**41.8 ± 16.1**	29.5 ± 5.2	27.1 ± 12.6	$F = 0.3, p = 0.90$ (0.03)
GM EC (%MVC)	72.7 ± 8.9	62.3 ± 12.5	59.4 ± 8.1	67.8 ± 11.0	93.9 ± 11.7	**117.1 ± 30.3**	$F = 2.3, p = 0.06$ (0.19)
GM CON (%MVC)	63.4 ± 9.2	62.9 ± 8.3	75.3 ± 7.0	65.2 ± 5.7	64.7 ± 6.3	**76.3 ± 4.9**	$F = 0.7, p = 0.66$ (0.06)
VM EC (%MVC)	68.6 ± 9.0	54.8 ± 6.6	75.2 ± 8.2	95.0 ± 18.2	96.0 ± 11.4	**104.4 ± 24.5**	$F = 2.1, p = 0.08$ (0.18)
VM CON (%MVC)	52.5 ± 7.0	65.4 ± 8.9	**72.3 ± 11.8**	52.0 ± 11.0	64.4 ± 9.8	58.1 ± 14.4	$F = 0.6, p = 0.68$ (0.06)
BF EC/CON ratio	1.6 ± 0.4	1.4 ± 0.2	1.0 ± 0.1	1.7 ± 0.3	1.5 ± 0.5	**3.2 ± 0.9**[a]	**$F = 2.7, p = 0.03$ (0.21)**
GM EC/CON ratio	1.5 ± 0.4	1.1 ± 0.2	0.9 ± 0.2	1.2 ± 0.3	1.6 ± 0.3	**1.7 ± 0.6**	$F = 1.1, p = 0.38$ (0.1)
VM EC/CON ratio	1.4 ± 0.2	1.0 ± 0.2	1.2 ± 0.2	2.4 ± 0.7	1.8 ± 0.4	**2.5 ± 0.9**	$F = 1.8, p = 0.13$ (0.16)

Data are mean ±SEM.

BF, biceps femoris; CON, concentric; DJ15-DJ90, drop jump from 15 to 90-cm boxes, respectively; GM, gastrocnemius medialis; EC, eccentric; MVC, maximal voluntary contraction; VM, vastus medialis.

[a]*Significantly greater compared to DJ45 ($p < 0.05$). η_p^2: partial eta-squared. Bold values: highest performance and sEMG values for each variable across drop heights.*

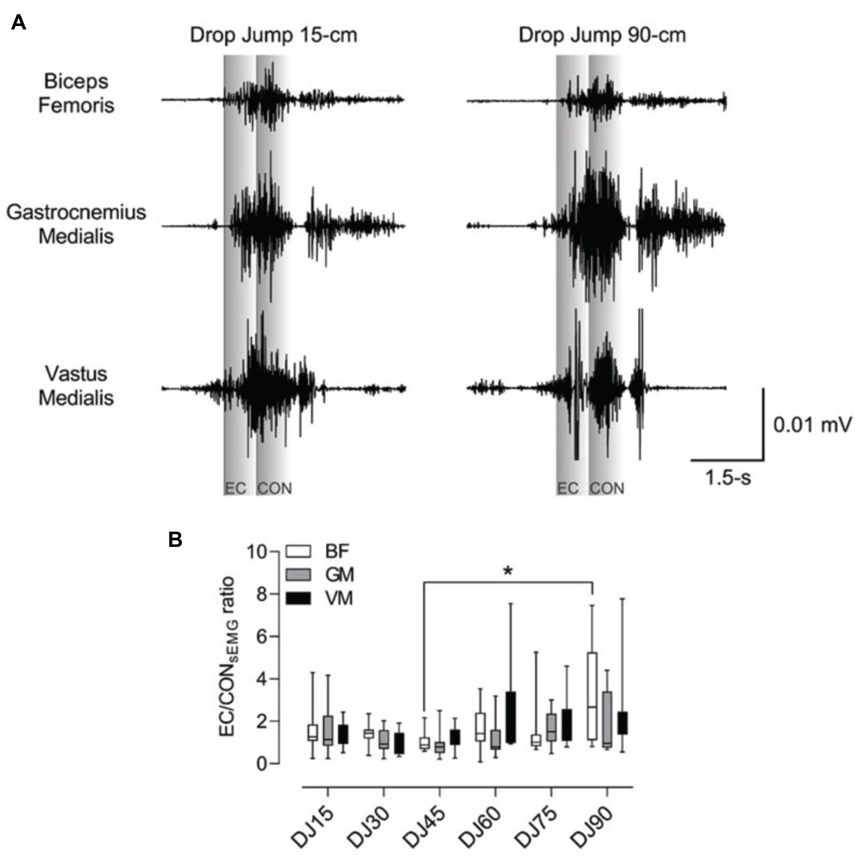


FIGURE 2 | Eccentric (EC) to concentric (CON) surface electromyography (sEMG) ratio in the biceps femoris (BF), gastrocnemius medialis (GM), and vastus medialis (VM) muscles of female volleyball athletes. **(A)** Representative sEMG recording from BF, GM, and VM of one athlete performing drop jumps from 15 cm (DJ15) and to 90 cm (DJ90). **(B)** Note that compared to the EC/CON sEMG BF ratio achieved after DJ45 (i.e., 1.0), a significantly ($p = 0.03$) greater ratio was observed after DJ90 (i.e., 3.2). Data are showed as median and interquartile range, $n = 10$. *Significantly ($p = 0.03$) greater after DJ90 compared to DJ45.

DJ30 may induce vGRF $\geq$4 times body mass in females athletes (McNair and Prapavessis, 1999), potentially contributing to knee instability and non-contact ACL injury (Yu and Garrett, 2007). Therefore, for amateur female volleyball athletes, in order to increase performance and reduce injury risk, the use of moderate height boxes (e.g., $\leq$DJ30) may be preferred over greater box heights.

Of note, although no significant concentric or eccentric sEMG differences were shown between DJ box heights, the highest values of sEMG activity usually occurred from greater DJ box heights, although the jumping parameters (i.e., reactive strength index) achieved relatively better performance at lower DJs box heights. Reduced jumping performance from higher DJ box drop heights might be related to neuromuscular inhibition, which serves as a protective mechanism to prevent muscle and tendon injury from excessive stress in the muscle-tendon unit (Komi, 2008). However, a greater jumping performance may not necessarily coincide with RMS of sEMG activity (Andrade et al., 2020). This might be explained by the reutilization of elastic energy due to the interaction between contractile elements and a series of elastic elements (Bobbert et al., 1996), gearing greater jumping performance independent of electrical activity. This notion is reinforced by the fact that at greater DJ box height (i.e., 90 cm), a $\sim$23% increase in contact time was noted compared to lower drop height (i.e., 15 cm), thus increasing elastic energy loss due to a prolonged SSC (Asmussen and Bonde-Petersen, 1974), yielding a relatively reduced jumping performance and an increased sEMG activity. In the present study, sEMG activity was normalized to MVIC to compensate for differences in strength, muscle tone, fat mass, and muscle geometry among other factors that may induce bias in the results (Ankrum, 2000). However, in the literature, different methodologies have been used to assess neuromuscular parameters (Ebben et al., 2008, 2010; Peng et al., 2011), yielding different results. Although no consensus exists (Ebben et al., 2008; Peng et al., 2011), current results agree with the notion that moderate drop heights during DJ allow maximization of performance, including volleyball players (Andrade et al., 2020). In addition, it must be considered that the sEMG eccentric/concentric ratio may be particularly sensitive to changes in jumping intensity (Andrade et al., 2020) as indicated by the greater biceps femoris sEMG eccentric/concentric ratio after DJ90 compared to DJ45. Such result was in line with a tendency for decreased biceps femoris concentric sEMG and increased biceps femoris eccentric sEMG at greater DJ heights. Such findings may be related to the eccentric involvement of the biceps femoris at the hip joint to decelerate the center of mass at landing, with potential implications for hamstring strain injury risk reduction (Bourne et al., 2018).

Taken together, our results suggest that motor unit recruitment does not change across DJ box heights during the eccentric and concentric phases. This observation remains for different muscles (biceps femoris, vastus medialis, and gastrocnemius medialis) and different muscle actions (agonist and antagonist). Therefore, it is debatable if a greater DJ drop height is indicative of greater intensity. Based on recent results, the 50–100% of maximal countermovement jump height may be the appropriate individual relative drop height for the DJ among volleyball players (Peng et al., 2019). Future studies should analyze the effects of adequate (individualized) prescription of drop heights for the DJ on the physical fitness and injury risk among female volleyball players, as previously resolved in other groups of athletes (Ramirez-Campillo et al., 2018a, 2019). Further, DJ drills are meant to be performed usually with a contact time of <250 ms. Of note, although all athletes have $\geq$2 years of regular training and competition experience in volleyball, is striking that almost all of them did not attain a contact time <250 ms during the different DJ heights. Indeed, only one of the female volleyball athletes managed to achieve such a performance, potentially highlighting that athletes were not appropriately conditioned to gain the maximal benefits from this task. Therefore, relative strength on DJ performance, particularly among female, including female volleyball athletes (Beckham et al., 2019), may be a factor for strength and conditioning coaches and researchers to consider.

Limitations

Some limitations should be acknowledged. Firstly, it would be risky to extrapolate current findings to other highly trained female volleyball groups, especially those with extensive strength and conditioning preparation, particularly resistance training preparation. Secondly, during the DJ testing session, all the players (except one) achieved contact time >250 ms. On one side, such contact time are commonly observed in the jumping actions of volleyball competitions, meaning high ecological validity for the current findings. However, if current findings may be extrapolated to DJ drills involving fast SSC muscle action, or ground foot contact time <250 ms, also referred as bounce DJ (Bobbert, 1990), should be clarified in future research. Thirdly, drop height is influenced by box height (Geraldo et al., 2019), and a modulation of drop height from greater box heights (e.g., stepping down from the box) may have (inadvertently) occurred, decreasing the height the center of mass drops from. We recommend controlling the center of mass displacement adding cinematic analysis of this variable to confirm or discard the aforementioned. Fourthly, our small sample size may raise some questions on the external validity of these results, particularly since recruited athletes comes from different playing positions (e.g., libero, and setter), and with different training backgrounds (i.e., $\geq$2 years of volleyball experience). Future studies may consider the inclusion of amateur players but with more years of experience. Finally, the study design (cross-sectional) does not allow inferring cause-effect relationships. Therefore, extrapolation of current findings to training interventions should be performed with caution.

CONCLUSION

Our results show that contact time, jump height, reactive strength index, as well as biceps femoris, medial gastrocnemius, and vastus medialis muscles sEMG (i.e., both concentric, eccentric, and eccentric/concentric ratio) were not significantly affected by DJs performed from different drop heights (i.e., DJ15, DJ30, DJ45, DJ60 DJ75, and DJ90), except for a greater biceps femoris eccentric/concentric ratio from DJ90 compared to DJ45. Therefore, DJ performance variables (jump height, contact time, and reactive strength index) concomitant to sEMG of lower limb muscles during DJs from different box heights (intensities) are not sensitive markers to DJ box height (intensity) in amateur female volleyball athletes. In other words, increasing the box heights for DJs may not induce greater training stimulus (i.e., intensity).

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the local university (UST, CODE: N155/2018-code 195.18) and were based on the latest version of the Helsinki declaration. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors made significant contributions, including preparation of the first draft of the manuscript, data collection, analysis of data, interpretation of data, and provided meaningful revision and feedback. All authors read and approved the final manuscript.

REFERENCES

Aboodarda, S. J., Byrne, J. M., Samson, M., Wilson, B. D., Mokhtar, A. H., and Behm, D. G. (2014). Does performing drop jumps with additional eccentric loading improve jump performance? *J. Strength Cond. Res.* 28, 2314–2323. doi: 10.1519/JSC.0000000000000498

ACSM (2009). American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med. Sci. Sports Exerc.* 41, 687–708. doi: 10.1249/MSS.0b013e3181915670

Andrade, D. C., Henriquez-Olguín, C., Beltrán, A. R., Ramírez, M. A., Labarca, C., Cornejo, M., et al. (2015). Effects of general, specific and combined warm-up on explosive muscular performance. *Biol. Sport* 32, 123–128. doi: 10.5604/20831862.1140426

Andrade, D. C., Manzo, O., Beltrán, A. R., Álvarez, C., Del Rio, R., Toledo, C., et al. (2020). Kinematic and neuromuscular measures of intensity during plyometric jumps. *J. Strength Cond. Res.* 34, 3395–3402. doi: 10.1519/JSC.0000000000002143

Ankrum, D. R. (2000). Questions to ask when interpreting surface electromyography (SEMG) research. *Proc. Hum. Fact. Ergon. Soc. Annu. Meet.* 44, 530–535. doi: 10.1177/154193120004403036

Asmussen, E., and Bonde-Petersen, F. (1974). Storage of elastic energy in skeletal muscles in man. *Acta Physiol. Scand.* 91, 385–392. doi: 10.1111/j.1748-1716.1974.tb05693.x

Barnes, J. L., Schilling, B. K., Falvo, M. J., Weiss, L. W., Creasy, A. K., and Fry, A. C. (2007). Relationship of jumping and agility performance in female volleyball athletes. *J. Strength Cond. Res.* 21, 1192–1196. doi: 10.1519/00124278-200711000-00036

Beckham, G. K., Suchomel, T. J., Sole, C. J., Bailey, C. A., Grazer, J. L., Kim, S. B., et al. (2019). Influence of sex and maximum strength on reactive strength index-modified. *J. Sports Sci. Med.* 18, 65–72.

Bobbert, M. F. (1990). Drop jumping as a training method for jumping ability. *Sports Med.* 9, 7–22. doi: 10.2165/00007256-199009010-00002

Bobbert, M. F., Gerritsen, K. G., Litjens, M. C., and Van Soest, A. J. (1996). Why is countermovement jump height greater than squat jump height? *Med. Sci. Sports Exerc.* 28, 1402–1412. doi: 10.1097/00005768-199611000-00009

Bobbert, M. F., Huijing, P. A., and Van Ingen Schenau, G. J. (1987a). Drop jumping. I. The influence of jumping technique on the biomechanics of jumping. *Med. Sci. Sports Exerc.* 19, 332–338. doi: 10.1249/00005768-198708000-00003

Bobbert, M. F., Huijing, P. A., and Van Ingen Schenau, G. J. (1987b). Drop jumping. II. The influence of dropping height on the biomechanics of drop jumping. *Med. Sci. Sports Exerc.* 19, 339–346. doi: 10.1249/00005768-198708000-00004

Bourne, M. N., Timmins, R. G., Opar, D. A., Pizzari, T., Ruddy, J. D., Sims, C., et al. (2018). An evidence-based framework for strengthening exercises to prevent hamstring injury. *Sports Med.* 48, 251–267. doi: 10.1007/s40279-017-0796-x

Brumitt, J., Heiderscheit, B. C., Manske, R. C., Niemuth, P., Mattocks, A., and Rauh, M. J. (2016). The lower-extremity functional test and lower-quadrant injury in NCAA division III athletes: a descriptive and epidemiologic report. *J Sport Rehabil* 25, 219–226. doi: 10.1123/jsr.2014-0316

De Alcaraz, A. G., Valadés, D., and Palao, J. M. (2017). Evolution of game demands from young to elite players in men's volleyball. *Int. J. Sports Physiol. Perform.* 12, 788–795. doi: 10.1123/ijspp.2016-0027

Disselhorst-Klug, C., and Williams, S. (2020). Surface electromyography meets biomechanics: correct interpretation of sEMG-signals in neuro-rehabilitation needs biomechanical input. *Front. Neurol.* 11:603550. doi: 10.3389/fneur.2020.603550

Ebben, W. P., Fauth, M. L., Garceau, L. R., and Petushek, E. J. (2011). Kinetic quantification of plyometric exercise intensity. *J. Strength Cond. Res.* 25, 3288–3298. doi: 10.1519/JSC.0b013e31821656a3

Ebben, W. P., Fauth, M. L., Petushek, E. J., Garceau, L. R., Hsu, B. E., Lutsch, B. N., et al. (2010). Gender-based analysis of hamstring and quadriceps muscle activation during jump landings and cutting. *J. Strength Cond. Res.* 24, 408–415. doi: 10.1519/JSC.0b013e3181c509f4

Ebben, W. P., Simenz, C., and Jensen, R. L. (2008). Evaluation of plyometric intensity using electromyography. *J. Strength Cond. Res.* 22, 861–868. doi: 10.1519/JSC.0b013e31816a834b

Faul, F., Erdfelder, E., Lang, A. G., and Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: /10.3758/BF03193146

Flanagan, E., and Comyns, T. (2008). The use of contact time and the reactive strength index to optimize fast stretch-shortening cycle training. *Strength Cond. J.* 30, 32–38. doi: 10.1519/SSC.0b013e318187e25b

Fritz, C. O., Morris, P. E., and Richler, J. J. (2012). Effect size estimates: current use, calculations, and interpretation. *J. Exp. Psychol. Gen.* 141, 2–18. doi: 10.1037/a0024338

Fuchs, P. X., Menzel, H. K., Guidotti, F., Bell, J., Von Duvillard, S. P., and Wagner, H. (2019). Spike jump biomechanics in male versus female elite volleyball players. *J. Sports Sci.* 37, 2411–2419. doi: 10.1080/02640414.2019.1639437

Gabbett, T. J. (2016). The training-injury prevention paradox: should athletes be training smarter and harder? *Br. J. Sports Med.* 50, 273–280. doi: 10.1136/bjsports-2015-095788

García-De-Alcaraz, A., Ramírez-Campillo, R., Rivera-Rodríguez, M., and Romero-Moraleda, B. (2020). Analysis of jump load during a volleyball season in terms of player role. *J. Sci. Med. Sport* 23, 973–978. doi: 10.1016/j.jsams.2020.03.002

Geraldo, G. D. F., Bredt, S. D. G. T., Menzel, H.-J. K., Cançado, G. H. D. C. P., Carvalho, L. A. C. M., Lima, F. V., et al. (2019). Drop height is influenced by box height but not by individual stature during drop jumps. *J. Phys. Educ.* 30:3078.

Gonzalez-Izal, M., Malanda, A., Gorostiaga, E., and Izquierdo, M. (2012). Electromyographic models to assess muscle fatigue. *J. Electromyogr. Kinesiol.* 22, 501–512. doi: 10.1016/j.jelekin.2012.02.019

Heiderscheit, B. C., Mclean, K. P., and Davies, G. J. (1996). The effects of isokinetic vs. plyometric training on the shoulder internal rotators. *J. Orthop. Sports Phys. Ther.* 23, 125–133. doi: 10.2519/jospt.1996.23.2.125

Hopkins, W. G., Marshall, S. W., Batterham, A. M., and Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Med. Sci. Sports Exerc.* 41, 3–13. doi: 10.1249/MSS.0b013e31818cb278

Jensen, R. L., and Ebben, W. P. (2007). Quantifying plyometric intensity via rate of force development, knee joint, and ground reaction forces. *J. Strength Cond. Res.* 21, 763–767. doi: 10.1519/00124278-200708000-00018

Komi, P. (2008). *Stretch-Shortening Cycle*. Cham: Springer, 184–202. doi: 10.1002/9780470757215.ch10

Koo, T. K., and Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J. Chiropr. Med.* 15, 155–163. doi: 10.1016/j.jcm.2016.02.012

Krommes, K., Bandholm, T., Jakobsen, M. D., Andersen, L. L., Serner, A., Hölmich, P., et al. (2017). Dynamic hip adduction, abduction and abdominal exercises from the holmich groin-injury prevention program are intense enough to be considered strengthening exercises - a cross-sectional study. *Int. J. Sports Phys. Ther.* 12, 371–380.

Lenhardt, S. A., Mcintosh, K. C., and Gabriel, D. A. (2009). The surface EMG-force relationship during isometric dorsiflexion in males and females. *Electromyogr. Clin. Neurophysiol.* 49, 227–234.

Lloyd, R. S., Meyers, R. W., and Oliver, J. L. (2011). The natural development and trainability of plyometric ability during childhood. *Strength Condition. J.* 33, 23–32. doi: 10.1519/SSC.0b013e3182093a27

McNair, P. J., and Prapavessis, H. (1999). Normative data of vertical ground reaction forces during landing from a jump. *J. Sci. Med. Sport* 2, 86–88. doi: 10.1016/S1440-2440(99)80187-X

Peng, H.-T., Kernozek, T. W., and Song, C.-Y. (2011). Quadricep and hamstring activation during drop jumps with changes in drop height. *Phys. Ther. Sport* 12, 127–132. doi: 10.1016/j.ptsp.2010.10.001

Peng, H. T., Song, C. Y., Wallace, B. J., Kernozek, T. W., Wang, M. H., and Wang, Y. H. (2019). Effects of relative drop heights of drop jump biomechanics in male volleyball players. *Int. J. Sports Med.* 40, 863–870. doi: 10.1055/a-0969-8623

Ramirez-Campillo, R., Alvarez, C., Garcia-Hermoso, A., Ramirez-Velez, R., Gentil, P., Asadi, A., et al. (2018a). Methodological characteristics and future directions for plyometric jump training research: a scoping review. *Sports Med.* 48, 1059–1081. doi: 10.1007/s40279-018-0870-z

Ramirez-Campillo, R., Alvarez, C., García-Pinillos, F., Gentil, P., Moran, J., Pereira, L. A., et al. (2019). Effects of plyometric training on physical performance of young male soccer players: potential effects of different drop jump heights. *Pediatr. Exerc. Sci.* 31, 306–313. doi: 10.1123/pes.2018-0207

Ramirez-Campillo, R., Alvarez, C., García-Pinillos, F., Sanchez-Sanchez, J., Yanci, J., Castillo, D., et al. (2018b). Optimal reactive strength index: is it an accurate variable to optimize plyometric training effects on measures of physical fitness in young soccer players? *J. Strength Cond. Res.* 32, 885–893. doi: 10.1519/JSC.0000000000002467

Ramirez-Campillo, R., Andrade, D. C., and Izquierdo, M. (2013). Effects of plyometric training volume and training surface on explosive strength. *J. Strength Cond. Res.* 27, 2714–2722. doi: 10.1519/JSC.0b013e318280c9e9

Serner, A., Jakobsen, M. D., Andersen, L. L., Hölmich, P., Sundstrup, E., and Thorborg, K. (2014). EMG evaluation of hip adduction exercises for soccer players: implications for exercise selection in prevention and treatment of groin injuries. *Br. J. Sports Med.* 48, 1108–1114. doi: 10.1136/bjsports-2012-091746

Sheppard, J. M., Gabbett, T., Taylor, K. L., Dorman, J., Lebedew, A. J., and Borgeaud, R. (2007). Development of a repeated-effort test for elite men's volleyball. *Int. J. Sports Physiol. Perform.* 2, 292–304. doi: 10.1123/ijspp.2.3.292

Silva, A. F., Clemente, F. M., Lima, R., Nikolaidis, P. T., Rosemann, T., and Knechtle, B. (2019). The effect of plyometric training in volleyball players: a systematic review. *Int. J. Environ. Res. Public Health* 16, 2960–2983. doi: 10.3390/ijerph16162960

Sipavičiené, S., Daniusevièiutë, L., Klizienë, I., Kamandulis, S., and Skurvydas, A. (2013). Effects of estrogen fluctuation during the menstrual cycle on the response to stretch-shortening exercise in females. *Biomed. Res. Int.* 2013:243572. doi: 10.1155/2013/243572

Stokes, M. (1985). Reliability and repeatability of methods for measuring muscle in physiotherapy. *Physiother. Pract.* 1, 71–76. doi: 10.3109/09593988509163853

Taube, W., Leukel, C., and Gollhofer, A. (2012). How neurons make us jump: the neural control of stretch-shortening cycle movements. *Exerc. Sport Sci. Rev.* 40, 106–115. doi: 10.1097/JES.0b013e31824138da

Walker, S., Davis, L., Avela, J., and Hakkinen, K. (2012). Neuromuscular fatigue during dynamic maximal strength and hypertrophic resistance loadings. *J. Electromyogr. Kinesiol.* 22, 356–362. doi: 10.1016/j.jelekin.2011.12.009

Yu, B., and Garrett, W. E. (2007). Mechanisms of non-contact ACL injuries. *Br. J. Sports Med.* 41(Suppl. 1), i47–i51. doi: 10.1136/bjsm.2007.037192

Ziv, G., and Lidor, R. (2010). Vertical jump in female and male volleyball players: a review of observational and experimental studies. *Scand. J. Med. Sci. Sports* 20, 556–567. doi: 10.1111/j.1600-0838.2009.01083.x

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Psychology

ORIGINAL RESEARCH
published: 22 October 2021
doi: 10.3389/fpsyg.2021.719572

Check for updates

Personality Traits and Emotion Regulation Styles of Elite Beach Volleyball Dyads: Examination of Intra-Team Differences, Performance and Satisfaction Levels

Stefanie Klatt[1,2†], Lisa-Marie Rückel[1†], Sebastian Wagener[1] and Benjamin Noël[1]*

[1] *Institute of Exercise Training and Sport Informatics, German Sport University Cologne, Cologne, Germany,* [2] *School of Sport and Health Sciences, University of Brighton, Brighton, United Kingdom*

The current study was designed to assess the personality traits and emotion regulation styles of elite beach volleyball players. Intra-team differences were examined with three primary objectives: (i) to create a personality profile of elite beach volleyball players, (ii) to examine the relationship of this profile in relation to performance and satisfaction levels, and (iii) to highlight the similarities in personalities of members of successful teams. A total of 82 elite beach volleyball players were asked to fill out the Big Five Inventory, the Personality Adjective Scale, and the Affective Style Questionnaire. In addition to these, the overall satisfaction and performance level of these athletes were measured. Results indicated a higher manifestation of warmth, liveliness, emotional stability and reasoning, along with lower levels of neuroticism in successful athletes. The players used a variety of emotional regulation styles and reported being moderately to highly satisfied with their team. A repeated-measures MANCOVA revealed no significant differences in personality traits between the team members. This study generates valuable insights into the personality of elite beach volleyball players and can be useful for coaches, sport psychologists, and academics for practical application and further scientific research.

Keywords: volleyball association, dyads, performance, team composition, personality

Edited by:
Gibson Moreira Praça, Federal University of Minas Gerais, Brazil

Reviewed by:
Paweł Piepiora, University School of Physical Education in Wrocław, Poland
Luis Felipe Tubagi Polito, Universidade São Judas Tadeu, Brazil

****Correspondence:***
Stefanie Klatt
s.klatt@dshs-koeln.de

†These authors share first authorship

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *02 June 2021*
Accepted: *27 September 2021*
Published: *22 October 2021*

Citation:
Klatt S, Rückel L-M, Wagener S and Noël B (2021) Personality Traits and Emotion Regulation Styles of Elite Beach Volleyball Dyads: Examination of Intra-Team Differences, Performance and Satisfaction Levels. Front. Psychol. 12:719572. doi: 10.3389/fpsyg.2021.719572

INTRODUCTION

Practitioners of sports psychology and academics often refer to the general definition of a social group given by Sherif (1956) in order to define a sports team. According to this definition, a social group is defined by the interaction of two or more individuals who are dependent on each other and share common motives, interests, norms, values, and goals (Sherif, 1956; Forsyth, 2014). When group members commit themselves to the group, it results in feelings of cohesion and unity (Sherif, 1956; Forsyth, 2014).

However, with regard to a sports team, age, gender, playing position, technique, performance, and physical as well as functional parameters are more relevant as unifying factors than sharing equal norms and values (Trninić et al., 2008; Dadelo et al., 2014; Budak et al., 2018). The primary goal of high-performing teams is to win competitions and an efficient team is characterized by coordinated actions and cognitions of the team members (Bourbousson et al., 2010; Santos et al., 2018). While the emphasis in sports mainly lies on performance, teams are, in fact, seen as social groups. Therefore, the overall influence of shared norms, values, and personality traits could also play an important role in the success of the team and lead to enhanced teamwork and intra-team coordination.

Sports administrators, scouts, and coaches may have to consider these aspects to identify individuals who can form sustainable, high-performance teams. During the second stage of team development (*storming*) especially, conflicts and personality clashes can occur which need to be resolved urgently for the team to be cohesive and perform at a high level (Tuckman, 1965). This phase is particularly crucial for teams of smaller sizes, e.g., beach volleyball teams. Research shows that a good relationship and unity between team members is of greater importance for small teams in comparison to larger team sizes (Carron and Spink, 1995). It is also noteworthy that enjoyment and cohesion tends to decrease with an increase in the team size (Widmeyer et al., 1990).

The smallest team size is a dyad or a pair which is composed of two individuals (Becker and Useem, 1942). A dyad might require a closer relationship between both team members to maintain harmony and enable better team functioning. Compared to bigger groups, dyads cannot be broken down into sub-groups and split up when one member leaves (Forsyth, 2014). Therefore, dyad members are strongly inter-dependent and often show deep emotional bonds (Levine and Moreland, 2012). It is this codependence which makes the role of individual personality traits, beliefs, and values in a dyad unclear.

The personality of an individual is defined as a stable set of characteristics that influence and shape cognition, emotions, and behavior of that individual in various situations (Ryckman, 2012). In order to better understand and predict human behavior, researchers have tried to place human personality within the constructs of scientific models. So far, several personality models and theories thereof, have been shaped by the evolution and development of the broader field of psychology and philosophy. Trait psychology theories are the most scientific, research-based approach of describing human personality (Ellis et al., 2009). Traits are aspects of personality that are stable over time and across various situations. They have a certain measurable range of manifestation and differ among individuals (Boyle et al., 2008; Ellis et al., 2009).

In the past, several models of trait personality have been developed for research into this subject area, beginning with Allport (1937), Cattell (1943, 1973) and Eysenck (1957). Cattell was the first to develop a scientific measurement of trait personality by the use of a statistical factor analysis. He identified 16 personality traits like reasoning, warmth, emotional stability, and openness to change as the basis for his 16 Personality Factor Questionnaire (16 PF; Cattell, 1943). Eysenck (1957, 1967) built on this approach; however, he only focused on the three dimensions of extraversion, neuroticism, and psychoticism. The last and so far the most accepted personality trait theory is the Five Factor Model (FFM) based on the work of Goldberg (1990) and Costa and McCrae (1992a). The authors hypothesized that personality can be described best by five factors: extraversion, neuroticism, openness to experience, agreeableness, and conscientiousness (for detailed information about the factors, see Costa and McCrae, 1992b).

For years, sports psychologists have focused on the relationship between individual personality characteristics and success. What has emerged is that certain personality traits have an influence not only on the performance and success of the individual athlete (Allen et al., 2013), but also of the whole team (Halfhill et al., 2005). A review by Allen et al. (2013) discovered that elite athletes have higher levels of extraversion, conscientiousness, and agreeableness and lower level of neuroticism. These findings were related to success, effective coping, and mental preparation (Woodman et al., 2010). Compared to individual sports athletes, team sports athletes appear to be more extraverted and less conscientious (Eagleton et al., 2007; Allen et al., 2011). In spite of these findings, scientific inquiry on optimal distribution of personality traits within teams remains limited (Allen et al., 2013; Berger et al., 2015).

In studies by Schurr et al. (1977) and Kirkcaldy (1982) differences in the personalities within the team have been examined. Results show that offensive players tend to be more extraverted than team members playing defense. However, these results have not been confirmed by recent research (Jackson et al., 2010, 2011). Cameron et al., 2012 found that dissimilarities in the personality traits of extraversion and openness between dyadic team partners were associated with a higher probability of conflicts and dysfunctional intra-team relationships.

Based on the findings by Jackson et al. (2010, 2011), it can be proposed that personality and characteristics, specifically, similar beliefs, norms, and values, of both players within a dyadic team might be a crucial aspect in team formation and sustenance. In order to achieve harmony, good intra-team relationships and efficiency leading to success, coaches or scouts may wish to consider building dyadic teams consisting of similar personalities (Budak et al., 2018). However, teams are sometimes more efficient and successful if team members, who differ in their personalities, have unique and diverse attributes (Beebe and Masterson, 2010; Gilley et al., 2010). Mohammed and Angell (2003) investigated the performance of and relationship between differences in personality traits across 267 business students in 59 working teams. They found that overall differences in agreeableness and neuroticism resulted in poorer performance, whereas high variability of extraversion led to better performance.

Therefore, with this study, we have tried to provide further information about the role of the personalities of elite beach volleyball players within teams. The goal of this study was threefold: (1) creation of a personality profile of elite beach volleyball players, (2) examination of the relationship with their performance and satisfaction and (3) observation of personality differences between the members of a dyadic team. As most existing research has only considered the Big Five Personality Traits, we additionally integrated the 16 personality factors of Cattell (1943). We also included emotion regulation styles into our research as it is strongly associated with personality and is an important factor in elite sport (Uphill et al., 2012; Allen and Laborde, 2014; Barańczuk, 2019). Based on initial research, we formulated the following hypotheses:

Hypothesis 1: Elite beach volleyball players exhibit more characteristics of extraversion, agreeableness, openness, and fewer characteristics of neuroticism.

Hypothesis 2: Performance of elite beach volleyball players has a positive correlation with the personality traits of extraversion, agreeableness and conscientiousness and a negative correlation to neuroticism.

Hypothesis 3: Elite beach volleyball teams show high level of similarity of personality characteristics within their team.

MATERIALS AND METHODS

For data collection, we used an online survey[1] and provided it digitally to the Top 50 of the German Volleyball Association. We also approached regional associations and 16 of the best female and male regional beach volleyball teams provided data through a paper-pencil test.

Participants

For this study, only beach volleyball teams were considered. As the organizational rules of beach volleyball do not allow a coach to stand on the sideline during a competition (see official rules from the Fédération Internationale de Volleyball [FIVB], 2016), the team members have to interact, change tactics, and solve problems together among themselves without any external help. We also considered that beach volleyball players, in contrast to doubles teams in other sports like badminton or tennis, need to pass each other the ball and therefore, are equally responsible for the success or failure of the team.

A total of 82 beach volleyball athletes participated in the study, which was carried out from July to September 2017. Of those, 46 were male and 36 were female. The mean age of the participants was 26.39 ($SD = 4.32$) years and 31 played the position of block (37.8%), 34 of defense (41.5%) and 17 played both the positions alternately (20.7%). The criteria for the selection of the subjects were: (1) they could name a standard beach volleyball partner who also participated in the study; (2) they participated actively in tournaments in the 2017 season; (3) they were at least 18 years old; (4) they had the experience of participating in national competitions (at least A[2] level), and (5) they signed informed consent approved by the ethics committee of the German Sport University Cologne (ethics proposal number: 135). The questionnaire, which was sent to them, assessed demographic variables, emotional regulation, personality type, level of satisfaction, and ranking points, which provided us an estimate on the performance level of an athlete. The study was carried out in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Measurements

Data about an athlete's personality was collected using the German Big-Five-Inventory-10 (BFI-10; by Rammstedt and John, 2007) and the German Personality Adjective Scale (PASK-5; Persönlichkeits-Adjektiv-Skalen) by Brandstätter (2009), which is based on Cattell's personality theory and questionnaire (Cattell, 1943; Cattell and Mead, 2008). The BFI-10 questionnaire consisted of 10 items that were rated on a 5-point Likert scale (1 = "disagree strongly"; 5 = "agree strongly") with a higher number indicating a greater compliance to the described statement. Five items (1, 3, 4, 5, and 7) had to be recoded. The identified personality dimensions were extraversion, neuroticism, openness to experience, conscientiousness, and Agreeableness (internal consistency from $\alpha = 0.58$ to $\alpha = 0.84$).

For the PASK5, participants rated opposing adjectives placed at the end of a 9-point Likert scale (e.g., 'reserved' – 'outgoing,' 'affected by feelings' – 'emotionally stable'; internal consistency from $\alpha = 0.53$ to $\alpha = 0.88$). We used the German version of the Affective Style Questionnaire (ASQ) from Graser et al. (2012; original version from Hofmann and Kashdan, 2010) for measuring the emotion regulation strategies in high-performance beach volleyball athletes. The self-report survey consisted of 20 items (e.g., 'I can tolerate strong emotions,' or 'I can calm myself down easily') that were ranked on a 5-point Likert scale (1 = "not true for me at all"; 5 = "extremely true for me") and averaged into one of the three regulation styles: Concealing (eight items), Adjusting (seven items), and Tolerating (five items). The ASQ is known to be a reliable and valid psychological measurement (internal consistency: suppression scale: $\alpha = 0.84$; adjusting scale: $\alpha = 0.75$; accepting scale: $\alpha = 0.72$ Graser et al., 2012).

Furthermore, we used the individual ranking points as an estimation for performance level. Ranking points were amassed by the athletes by competing in tournaments where both the team members earn points individually for their performance and placements on the ranking scale. The higher final placements in the competition lead to more ranking points. For example, when finishing third in a competition, both team members gain 75 points, but members of the team placed first, earn 100 points each[3]. The points system also differs when playing against elite or professional teams as opposed to amateur teams. Athletes sometimes participate in regional competitions with fewer elite and professional teams in order to gain experience and game practice. In that case, they earn fewer points even with the same final placement. That is, there are more ranking points to gain at national compared to regional tournaments. For example, finishing first at a regional competition will earn a player only 35 points. There are many factors for the differences in the rankings of players in the same team. For instance, athletes sometimes compete at one or several competitions with a different partner, e.g., in case their standard partner was injured. All ranking points are calculated at the end of the season.

[1] https://www.soscisurvey.de/

[2] "A level tournaments" are the highest ranked regional competitions. The ranking system is structured as the following (from lowest to highest): D level, C level, B level, A level (all regional), category 1, category 1+, and category 2 (all national). For further information on the regional level ranking see https://wp.beachvolleyball.nrw/wp-content/uploads/2021/07/Durchfuehrungsbestimmungen-WVV-Beachserie-2021_14.07.2021-Website.pdf, on national level ranking see https://www.volleyball-verband.de/?proxy=redaktion/Dokumente/Satzung-Ordnungen/Beach-Volleyball-Ordnung/2021/20210602_BVO_Anlage-F_Durchfuehrungsbestimmungen_LV_2021_V18.pdf; Both last accessed on 7th of September 2021.

[3] https://beach.volleyball-verband.de; Last accessed on 22nd of October 2020.

For the purpose of our research, the best eight tournament results were considered, and a ranking list of the best female and male teams and individual players was created. For this research, only the individual ranking points and performance level was considered. Lastly, the participants ranked their satisfaction with the team's success from 0 to 100%.

Statistical Analysis

The statistical analysis was in line with the three primary objectives of the study. First, descriptive statistics of the individual beach volleyball athletes' personality and emotional regulation were calculated. At this point we assessed gender differences by means of an analysis of variance (one-factor ANOVA) which revealed significant differences between both genders for warmth, $F(1,80) = 7.78$, $p = 0.01$, $\eta_p^2 = 0.09$, emotional stability, $F(1,80) = 7.13$, $p = 0.01$, $\eta_p^2 = 0.08$, dominance, $F(1,80) = 6.36$, $p = 0.01$, $\eta_p^2 = 0.07$, sensitivity, $F(1,80) = 12.33$, $p = 0.001$, $\eta_p^2 = 0.13$, apprehension, $F(1,80) = 13.81$, $p < 0.001$, $\eta_p^2 = 0.15$, and conscientiousness, $F(1,80) = 4.91$, $p = 0.03$, $\eta_p^2 = 0.06$. In contrast to the results by Graser et al. (2012), no significant differences between male and female participants' emotional regulation styles were found within our sample. In order to control for gender differences, gender was entered as covariate for further analysis.

Next, the values were compared to the norm using multiple one-sample t-tests. Here, the analysis was adjusted for each questionnaire by Bonferroni correction in order to prevent the accumulation of type 1 errors (Hervé, 2007). *A priori* power analysis ($d = 0.3$, $\alpha = 0.05$, power = 0.80) revealed a required sample size of $N = 71$.

The second goal of the study was to examine the relationship between personality, emotion regulation style, performance, and team satisfaction. Therefore, partial Pearson correlation was calculated (*a priori* power analysis: $N = 61$ for $d = 0.35$, $\alpha = 0.05$, power = 0.80).

In order to gather information on similarities or differences in personality traits of both team members, repeated measures MANCOVA analysis was applied (study goal 3). Here, the athlete's number of the team (athlete A or athlete B) was entered as within-subject factor, gender as covariate, and the scales of the questionnaires as dependent variables. For this analysis, a sample size of 34 was required ($d = 0.3$, $\alpha = 0.05$, power = 0.80). All the cases with some missing data were excluded and the significance level was set at $\alpha = 0.05$. All the statistical testing was done with IBM SPSS Statistics Version 27; power analyses were conducted with G*Power 3.1.9.2.

RESULTS

Personality of German Beach Volleyball Players

The elite beach volleyball players rated their overall satisfaction with their team's success at an average of 75.91% ($SD = 22.27$). The mean performance level was 2088.26 ($SD = 2020.28$), which represented approximately 209 national ranking points. The mean values of the personality questionnaires and the emotion regulation style are displayed in **Table 1** for all the players. The personality traits of agreeableness and openness to experience were the most reported; neuroticism the least. Compared to the norm (see Rammstedt and John, 2007: 'German population, both genders, all education levels, 18–35 years'), our sample revealed lower values for extraversion, $t(81) = -10.19$, $p < 0.001$, for agreeableness, $t(81) = -3.31$, $p = 0.001$, and for conscientiousness, $t(81) = -7.87$, $p < 0.001$, and higher values for neuroticism, $t(81) = 8.35$, $p < 0.001$.

For the personality factor questionnaire, reasoning, warmth, emotional stability, and perfectionism were the most definite adjectives described for the elite beach volleyball athletes. On the contrary, apprehension and abstractedness were present in fewer instances. Brandstätter (2009) presented norm values for different fields of application, including values for research purposes in his manual. Our sample exhibited higher values in liveliness, $t(81) = 7.65$, $p < 0.001$, tension, $t(81) = 12.26$, $p < 0.001$, openness to change, $t(81) = 5.52$, $p < 0.001$, reasoning, $t(81) = 7.42$, $p < 0.001$, emotional stability, $t(81) = 3.99$, $p < 0.001$, privateness, $t(81) = 6.55$, $p < 0.001$, and lower values in rule-conscientiousness, $t(81) = -4.19$, $p < 0.001$, compared to the norm.

The use of ASQ allowed us to analyze emotion regulation styles and the concrete characteristics of the respondents. Elite beach volleyball players showed high regulation toward their emotions. However, only marginal differences between concealing, adjusting, and tolerating were observed and this was in conformity with the estimated norm values by Graser et al. (2012) (all $p > 0.02$).

Relationship Between Personality and Performance

As the second objective of the study, the relationship between personality traits, emotional regulation styles, performance, and overall satisfaction was examined. Here, no significant relationship between performance level and personality and emotional regulation of the individual beach volleyball athletes were found[4]. In fact, the overall satisfaction was not related to any of the examined characteristics (all $p > 0.05$; see **Table 2**). However, we found significant relationships between the questionnaires, which are recorded in **Table 3**.

Personality Differences Within Beach Volleyball Teams

The third objective of the study was to determine whether the elite beach volleyball players within a team share the same personality characteristics or if team members differ in certain personality traits. The data from 40[5] elite beach volleyball teams was compared to assess that. As the results of the mean differences between the personality traits, personality factors,

[4] As performance level was compared to individual ranking points, no analysis examining personality differences and team performance were presented.

[5] From the 82 athletes, two athletes had to be excluded from intra-teams comparisons, as their partner did not provide complete data. Therefore, only 40 teams were included for the third objective of the study.

TABLE 1 | Mean values (and standard deviations) of the personality questionnaires and emotion regulation style of elite beach volleyball players.

	Personality Factors (PASK-5)							
	Warmth	**Reasoning**	**Emotional stability**	**Dominance**	**Liveliness**	**Rule-consciousness**	**Social boldness**	**Sensitivity**
All (*N* = 82)	6.49 (1.70)	7.21 (0.98)	6.49 (1.56)	5.01 (1.43)	6.12 (1.56)	5.82 (1.46)	5.99 (1.42)	5.46 (1.42)
Male (*N* = 46)	6.04 (1.87)	7.23 (0.90)	6.88 (1.47)	5.35 (1.57)	6.07 (1.67)	5.63 (1.53)	6.15 (1.44)	5.00 (1.29)
Female (*N* = 36)	7.06 (1.26)	7.18 (1.10)	5.99 (1.56)	4.57 (1.11)	6.19 (1.44)	6.07 (1.35)	5.79 (1.39)	6.04 (1.39)
	Vigilance	**Abstractedness**	**Privateness**	**Apprehension**	**Openness to change**	**Self-reliance**	**Perfectionism**	**Tension**
All (*N* = 82)	5.42 (1.44)	4.45 (1.57)	5.60 (1.52)	4.12 (1.57)	5.51 (1.65)	5.78 (1.67)	6.29 (1.51)	5.24 (0.77)
Male (*N* = 46)	5.70 (1.59)	4.27 (1.56)	5.62 (1.48)	3.59 (1.22)	5.42 (1.73)	5.96 (1.68)	6.45 (1.48)	5.35 (0.85)
Female (*N* = 36)	5.07 (1.16)	4.68 (1.56)	5.57 (1.59)	4.79 (1.71)	5.61 (1.57)	5.56 (1.66)	6.08 (1.53)	5.11 (0.64)
	Big Five Personality Traits (BFI-10)							
	Extraversion	**Neuroticisms**	**Openness to experience**	**Conscientiousness**	**Agreeableness**			
All (*N* = 82)	3.23 (0.47)	2.94 (0.55)	3.42 (0.72)	3.35 (0.67)	3.16 (0.64)			
Male (*N* = 46)	3.14 (0.40)	2.99 (0.52)	3.46 (0.79)	3.49 (0.59)	3.21 (0.65)			
Female (*N* = 36)	3.33 (0.52)	2.88 (0.59)	3.38 (0.64)	3.17 (0.73)	3.11 (0.63)			
	Affective Style (ASQ)							
	Concealing	**Adjusting**	**Tolerating**					
All (*N* = 82)	3.09 (0.71)	3.19 (0.65)	3.57 (0.59)					
Male (*N* = 46)	3.16 (0.69)	3.18 (0.71)	3.64 (0.57)					
Female (*N* = 36)	3.00 (0.72)	3.21 (0.56)	3.48 (0.62)					

and the emotion regulation style already suggest, only marginal differences in personality traits between the beach volleyball players of the same team exist (see **Table 4**). Moreover, the repeated measures MANCOVA showed no significant differences between both members of a team with regard to those dependent variables, $F(23,16) = 1.22$, $p = 0.35$. Therefore, it can be assumed that the elite beach volleyball teams are composed of rather similar than complementary personalities.

DISCUSSION

The current study was designed to assess the personality profiles of elite German beach volleyball players. It turned out that the personality trait of neuroticism was present more compared to the norm. However, extraversion, agreeableness, and conscientiousness were found less distinct. The personality profile of the players further revealed enhanced characteristics of liveliness, tension, openness to change, privateness, emotional stability, as well as reasoning, and reduced rule-conscientiousness. Moreover, the participating team members possessed well-established emotion regulation styles. In general, beach volleyball players can be characterized as spontaneous and lively. They value friendly social relationships, do not worry much, and are rather stable in their cognitive assessment (Brandstätter, 2009). They are focused as well as goal-oriented, and show high social competence (Allen et al., 2013). They also apply different emotion regulation styles that help them to deal with withdrawn affection and this leads them to remain focused on the match.

Even though, the study did not control for situational selection of the regulation strategies, it can be assumed that contextual variables have an influence on the selection of the emotion regulation strategies. In competitions, it is often beneficial to hide and conceal one's own emotions in order to prevent an opponent from capitalizing on them, e.g., insecurity (Gross and John, 2003; Graser et al., 2012). Additionally, reappraisal of situations and adjusting own reactions to negative events (e.g., own mistakes and provoking opponent) helps to remain calm and positive (Mauss et al., 2007). Lastly, having higher tolerance toward one's own emotions and accepting affects as they come, enhances an athlete's wellbeing and the ability to deal with stress (Campbell-Sills et al., 2006; Kashdan and Steger, 2006). Yet, previous results of a study establishing a relationship between personality traits – especially extraversion, conscientiousness, agreeableness – and performance (Allen et al., 2013) could not be confirmed as no significant relationship between personality and emotion regulation and performance were found. In our study, we only observed individual emotion regulation strategies. However, in team sports, it can be beneficial and, in fact, necessary to regulate one's teammate's emotions as well, e.g., to help a teammate cope with his/her emotions or to prevent a negative impact of such emotions on one's own emotions or performance (Campo et al., 2017). This interpersonal emotion regulation approach can

TABLE 2 | Relationship between elite beach volleyball players' personality, performance, and satisfaction.

$N = 82$	Performance r (p)	Satisfaction r (p)
Personality Factors (PASK-5)		
Warmth	0.00 (1.00)	−0.07 (0.53)
Reasoning	−0.10 (0.37)	−0.01 (0.92)
Emotional stability	0.21 (0.07)	0.10 (0.37)
Dominance	0.13 (0.24)	−0.16 (0.17)
Liveliness	−0.06 (0.58)	−0.05 (0.64)
Rule-conscientiousness	0.09 (0.45)	−0.00 (0.98)
Social boldness	0.08 (0.49)	0.00 (1.00)
Sensitivity	−0.05 (0.67)	0.09 (0.42)
Vigilance	−0.09 (0.45)	0.14 (0.20)
Abstractedness	−0.03 (0.78)	0.07 (0.53)
Privateness	0.05 (0.64)	−0.10 (0.40)
Apprehension	−0.03 (0.81)	−0.12 (0.29)
Openness to change	−0.02 (0.84)	0.11 (0.34)
Self-reliance	0.16 (0.16)	0.06 (0.61)
Perfectionism	0.16 (0.15)	−0.11 (0.33)
Tension	−0.06 (0.57)	−0.14 (0.23)
Big Five Personality Traits (BFI-10)		
Extraversion	0.13 (0.24)	0.10 (0.37)
Neuroticism	−0.18 (0.10)	0.03 (0.77)
Openness to experience	0.03 (0.82)	−0.06 (0.61)
Conscientiousness	−0.09 (0.45)	−0.13 (0.24)
Agreeableness	0.08 (0.51)	−0.18 (0.12)
Affective Style (ASQ)		
Concealing	0.03 (0.81)	−0.20 (0.86)
Adjusting	0.10 (0.40)	0.09 (0.44)
Tolerating	0.06 (0.63)	0.05 (0.67)

enable better communication, collaborative work and ultimately, better team functioning (Brandwein et al., 2021). There is further scope to examine interpersonal emotion regulation strategies within beach volleyball teams.

Furthermore, we analyzed the relationship between personality and emotion regulation styles with performance and satisfaction. No significant relationship between performance, satisfaction, and personality was found. Similarly, one study by Waleriańczyk and Stolarski (2021) found no relationship between the Big-Five personality traits and race performance. However, in this study, the authors controlled for perfectionism, which showed a positive correlation to performance as well as the personality trait of conscientiousness. Gyomber et al. (2016) controlled for further psychological variables, like coping mechanisms and anxiety as personality traits in relation to performance. They found that athletes that can cope with pressure and are able to overcome it to exhibit peak performance in demanding situations, have greater performance outputs. Furthermore, neuroticism was negatively related to performance. As previous research has indicated (e.g., Halfhill et al., 2005; Woodman et al., 2010; Allen et al., 2013; Piepiora, 2021), personality and other psychological variables like emotion regulation, perfectionism, or coping mechanisms, indeed contribute to the performance of an athlete and future research should go beyond the Big Five personality traits to include other psychological variables (Roberts and Woodman, 2017).

One possible explanation for our contradictory findings might be that the performance was compared to the earned ranking points of the players. Players who won a higher number of matches and competed at more tournaments achieved higher rankings than athletes who either competed at fewer tournaments and/or did not win as often. Consequently, the actual performance level might not have been represented adequately by ranking points, as a team can, for example, win a match despite playing poorly (subjectively rated poor performance) or lose a match despite playing well (subjectively rated good performance). Therefore, future research should consider subjective evaluations from athletes, coaches, etc. about performance as a part of the measurement.

Another methodological problem concerns the nature of sport performance. While personality seems a stable set of characteristics (Seligman et al., 2005), performance and success are season or competition dependent. However, during and across seasons or competitions (or even in matches), performance can be stable (e.g., several top-5 placements following each other, participation in highest level competitions for years) as well as unstable (e.g., variations in ranking, relegation and ascent), which is reflected in ranking points. It is, therefore, necessary to control for performance trends via longitudinal or time-series analyses. Additionally, it has to be examined whether personality as a stable characteristic contributes to immediate performance or only functions as a foundation for achieving peak performance. Nevertheless, it might also be the case that personality is not a valid predictor for success in beach volleyball. Aspects like athleticism, technique, tactic, self regulation (Klatt and Noël, 2020) and cognitive abilities, (e.g., decision making; Noël et al., 2016; Klatt and Smeeton, 2020, or gaze behavior, Hüttermann et al., 2018) might be of higher relevance within this sport so that these factors should also be considered in more detail in future research. In this relation it was recently found that, among others, at least in referee teams in different sports, not only individual cognitive abilities play a role, but that the ability to coordinate the behavior of different team members is important for guaranteeing a high level of team performance (cf. Fasold et al., 2019; Fasold et al., 2021; Klatt et al., 2021).

Another objective of the study was to examine whether personality characteristics of the players were similar within dyadic teams. Within our sample, only marginal intra-team and no overall significant differences between the personalities of both team members were found. *Post hoc* analyses (G*Power 3.1.92) revealed a test statistic power ($1 - \beta$) of 0.94. Therefore, we can conclude that German beach volleyball teams are usually composed of players sharing similar personality characteristics. Comparable results were found by Jackson et al. (2010, 2011) and Cameron et al. (2012), however, the overall results still remain inconclusive as König-Görögh et al. (2017) and Álvarez-Kurogi et al. (2019) found differences in personality of various positions within handball and futsal teams.

Similar personalities within dyadic teams were associated with fewer conflicts and better intra-team relationships (Jackson et al., 2010). However, some teams might be able to benefit from

TABLE 3 | Pearson correlation between the Big Five personality traits, personality adjective scales and emotion regulation styles of elite beach volleyball players.

***N* = 82**		**PE**	**S**	**W**	**R**	**ES**	**D**	**L**	**RC**	**SB**	**S**	**V**	**AB**	**PR**	**AP**	**OC**	**SR**	**PF**	**T**	**E**	**N**	**OE**	**C**	**AG**	**CL**	**AD**	**TO**
Performance PE	*r*	1	0.16	0.00	−0.10	0.21	0.13	−0.06	0.08	0.08	−0.05	−0.09	−0.03	0.05	−0.03	−0.02	0.16	0.16	−0.06	0.13	−0.18	0.03	−0.09	0.08	0.03	0.09	0.05
	p		0.15	1.00	0.37	0.07	0.24	0.57	0.45	0.49	0.67	0.45	0.78	0.63	0.81	0.84	0.16	0.15	0.57	0.23	0.10	0.82	0.45	0.51	0.81	0.40	0.63
Satisfaction S	*r*		1	−0.07	−0.01	0.10	−0.16	−0.05	0.00	0.00	0.09	0.14	0.07	−0.10	−0.12	0.11	0.06	−0.11	−0.14	0.10	0.03	−0.06	−0.13	−0.17	−0.02	0.09	0.05
	p			0.53	0.92	0.37	0.17	0.64	0.98	1.00	0.42	0.20	0.53	0.40	0.29	0.34	0.61	0.33	0.23	0.37	0.77	0.61	0.24	0.12	0.86	0.44	0.67
Warmth W	*r*			1	−0.05	0.07	0.01	0.47	*−0.37*	*0.46*	0.00	*−0.40*	*0.29*	−0.21	*−0.31*	*0.31*	−0.07	−0.06	0.12	0.05	0.06	0.12	−0.15	*0.22*	−0.09	0.05	0.19
	p				0.65	0.54	0.96	*0.00*	*0.00*	*0.00*	0.97	*0.00*	*0.01*	0.06	*0.01*	*0.00*	0.54	0.62	0.29	0.65	0.62	0.28	0.19	*0.04*	0.45	0.64	0.10
Reasoning R	*r*				1	0.20	0.12	0.04	0.10	0.20	0.01	0.08	*−0.28*	*0.34*	*−0.23*	0.04	0.21	*0.35*	*−0.29*	−0.18	−0.17	0.03	−0.14	−0.14	0.12	0.19	−0.09
	p					0.08	0.31	0.73	0.37	0.07	0.95	0.50	*0.01*	*0.00*	*0.04*	0.71	0.06	*0.00*	*0.01*	0.12	0.14	0.81	0.20	0.21	0.28	0.09	0.40
Emotional stability ES	*r*					1	0.02	0.04	−0.18	*0.25*	*−0.23*	−0.14	−0.08	−0.02	*−0.32*	0.16	0.09	*0.30*	−0.11	0.14	0.01	−0.15	−0.17	0.05	0.16	*0.30*	0.12
	p						0.83	0.73	0.11	*0.02*	*0.04*	0.20	0.50	0.87	*0.00*	0.14	0.43	*0.01*	0.33	0.20	0.93	0.17	0.13	0.67	0.14	*0.01*	0.27
Dominance D	*r*						1	*0.32*	0.05	*0.35*	*−0.28*	*0.23*	0.01	*−0.32*	−0.06	0.12	*0.32*	−0.05	0.06	−0.18	0.10	0.01	−0.14	0.08	−0.17	−0.13	−0.01
	p							*0.00*	0.67	*0.00*	*0.01*	*0.04*	0.94	*0.00*	0.59	0.28	*0.00*	0.65	0.57	0.11	0.39	0.93	0.20	0.46	0.12	0.26	0.93
Liveliness L	*r*							1	−0.20	*0.72*	*−0.28*	−0.05	*0.29*	*−0.44*	−0.18	*0.44*	0.02	−0.11	*0.27*	−0.12	0.00	0.18	−0.21	*0.24*	−0.19	−0.01	*0.31*
	p								0.07	*0.00*	*0.01*	0.68	*0.01*	*0.00*	0.11	*0.00*	0.87	0.31	*0.01*	0.30	0.98	0.12	0.06	*0.03*	0.09	0.96	*0.01*
Rule-consciousness RC	*r*								1	*−0.34*	0.15	0.14	*−0.44*	*0.43*	*0.35*	*−0.39*	0.14	*0.33*	−0.17	−0.09	−0.16	−0.14	0.03	−0.01	0.09	−0.01	−0.07
	p									*0.00*	0.19	0.22	*0.00*	*0.00*	*0.00*	*0.00*	0.21	*0.00*	0.12	0.41	0.15	0.22	0.76	0.90	0.42	0.92	0.52
Social boldness SB	*r*									1	*−0.33*	0.03	*0.29*	*−0.39*	*−0.41*	*0.48*	0.19	0.01	0.17	−0.07	−0.16	0.09	−0.22	*0.22*	−0.13	0.06	*0.26*
	p										*0.00*	0.80	*0.01*	*0.00*	*0.00*	*0.00*	0.08	0.94	0.12	0.55	0.16	0.43	0.05	*0.04*	0.25	0.60	*0.02*
Sensitivity S	*r*										1	*−0.24*	−0.05	*0.40*	0.08	*−0.28*	*−0.26*	0.07	0.01	0.04	0.02	0.03	0.07	0.02	−0.13	−0.16	−0.02
	p											*0.03*	0.66	*0.00*	0.47	*0.01*	*0.02*	0.53	0.95	0.75	0.89	0.80	0.52	0.86	0.26	0.15	0.85
Vigilance V	*r*											1	−0.11	−0.14	0.14	−0.13	*0.34*	−0.04	−0.03	−0.14	−0.11	−0.09	*−0.27*	−0.21	−0.04	*−0.28*	−0.04
	p												0.34	0.23	0.20	0.24	*0.00*	0.72	0.79	0.21	0.33	0.40	*0.02*	0.06	0.73	*0.01*	0.71
Abstractedness AB	*r*												1	*−0.36*	−0.07	*0.32*	−0.16	*−0.47*	*0.25*	−0.03	−0.01	0.19	−0.07	0.01	*−0.29*	−0.18	0.21
	p													*0.00*	0.54	*0.00*	0.16	*0.00*	*0.02*	0.77	0.92	0.10	0.52	0.96	*0.01*	0.12	0.06
Privateness PR	*r*													1	0.07	*−0.43*	0.02	*0.44*	−0.15	−0.07	−0.17	−0.20	−0.04	−0.11	0.15	0.16	*−0.23*
	p														0.53	*0.00*	0.87	*0.00*	0.18	0.54	0.13	0.07	0.75	0.34	0.17	0.15	*0.04*
Apprehension AP	*r*														1	*−0.30*	0.01	−0.05	−0.05	−0.10	0.02	0.00	0.08	−0.12	0.15	−0.07	*−0.23*
	p															*0.01*	0.91	0.65	0.63	0.36	0.88	0.98	0.48	0.29	0.20	0.55	*0.04*
Openness to change OC	*r*															1	0.16	−0.20	−0.02	−0.14	0.04	−0.08	−0.16	0.02	0.00	*0.24*	0.09
	p																0.15	0.07	0.88	0.21	0.74	0.48	0.16	0.87	0.98	*0.03*	0.42
Self-reliance SR	*r*																1	0.14	−0.11	*−0.28*	−0.16	−0.18	*−0.37*	−0.07	0.16	0.16	−0.02
	p																	0.21	0.31	*0.01*	0.15	0.12	*0.00*	0.55	0.15	0.16	0.87
Perfectionism PF	*r*																	1	*−0.32*	0.03	*−0.24*	−0.08	−0.03	−0.09	0.22	*0.30*	−0.04
	p																		*0.00*	0.80	*0.03*	0.46	0.78	0.40	0.05	*0.01*	0.71
Tension T	*r*																		1	−0.09	−0.05	−0.01	−0.02	0.12	−0.21	*−0.25*	*0.34*
	p																			0.41	0.68	0.95	0.83	0.29	0.06	*0.02*	*0.00*
Extraversion E	*r*																			1	0.16	−0.04	0.18	0.00	−0.03	−0.04	−0.03
	p																				0.14	0.75	0.11	0.98	0.77	0.70	0.81
Neuroticism N	*r*																				1	−0.07	0.16	−0.08	0.12	0.12	−0.12
	p																					0.52	0.14	0.50	0.27	0.29	0.27
Openness to experience OE	*r*																					1	0.18	0.20	−0.18	−0.10	0.15
	p																						0.11	0.08	0.12	0.37	0.19
Conscientiousness C	*r*																						1	0.06	0.13	0.04	−0.10
	p																							0.61	0.25	0.70	0.37
Agreeableness AG	*r*																							1	−0.14	−0.05	0.08
	p																								0.22	0.65	0.45
Concealing CL	*r*																								1	*0.62*	−0.21
	p																									*0.00*	0.06
Adjusting AD	*r*																									1	−0.06
	p																										0.62
Tolerating TO	*r*																										1
	p																										

Italics represent significant correlations.

TABLE 4 | Intra-team differences of personality and emotion regulation for elite beach volleyball teams ($N = 40$).

	Personality Factors (PASK-5)							
	Warmth	**Reasoning**	**Emotional stability**	**Dominance**	**Liveliness**	**Rule-consciousness**	**Social boldness**	**Sensitivity**
M (*SD*)	1.88 (1.33)	1.19 (0.86)	1.71 (1.04)	1.45 (1.15)	1.70 (1.31)	1.64 (1.32)	1.58 (1.28)	1.40 (1.37)
	Vigilance	**Abstractedness**	**Privateness**	**Apprehension**	**Openness to change**	**Self-reliance**	**Perfectionism**	**Tension**
M (*SD*)	1.64 (1.19)	1.70 (1.33)	1.76 (1.22)	1.73 (1.04)	2.01 (1.38)	1.81 (1.38)	1.44 (1.14)	0.89 (0.74)
	Big Five Personality Traits (BFI-10)							
	Extraversion	**Neuroticisms**	**Openness to experience**	**Conscientiousness**	**Agreeableness**			
M (*SD*)	0.48 (0.41)	0.53 (0.42)	0.84 (0.62)	0.65 (0.53)	0.70 (0.65)			
	Affective Style (ASQ)							
	Concealing	**Adjusting**	**Tolerating**					
M (*SD*)	0.70 (0.51)	0.73 (0.53)	0.71 (0.50)					

different personality characteristics (Mohammed and Angell, 2003; Beebe and Masterson, 2010; Gilley et al., 2010). Here, factors like similar goal setting, physical condition, motivation, and different as wells as complementary expertise are considered for team formation (Memmert et al., 2015; Budak et al., 2018). Therefore, both similarity and diversity within teams can be vital, depending on how diverse the requirements are for the different player positions within a sport or team (cf. Fasold et al., 2020). However, it is still unclear whether similar personalities in team sports are beneficial for performance and success. Future studies should, thus, include measurements of cohesion and relationship quality, conflict management, and team selection processes. As conflicts and relationship quality were influenced by personality, it could be that the beneficial effect of cohesion on success (e.g., see Carron et al., 2002) might be explained by similar personalities.

As no information about the team or player selection process was gathered, we cannot verify whether personality was at all considered during the beach volleyball team formation phase. Furthermore, it could be that the athletes themselves were either running the team selection process or had a great influence on it. As a result, player selection might unconsciously be influenced by preferences for a player sharing similar beliefs, norms, values, and personality traits.

There are some limitations and considerations for future research that need to be acknowledged. Within our study, we used self-reports to gain information about personality, emotion regulation, success/performance, and satisfaction of athletes within a beach volleyball team. We chose this approach because it minimized the time commitment for participants and allowed them to participate in the study despite a demanding time schedule during their season. Furthermore, our design did not allow for a cause-effect relationship. In order to gain a better understanding of personality and emotion regulation as predictors for success and satisfaction, an experimental design, which is more time consuming and requires an interference in training (or alternatively an additionally scheduled measurement), would be necessary.

CONCLUSION

The current study investigated the personality and emotion regulation styles of elite beach volleyball players. Within these teams, personality characteristics of the athletes were rather similar, and it can be assumed that teams generally consist of athletes who share certain personality traits and values. However, personality and emotion regulation were not related to the actual performance level as per our findings. Other motor (e.g., athleticism and technique) and psychological (e.g., cohesion and motivation) factors should be taken into account in future in order to find factors leading to peak performance. Additionally, as our research was only conducted in Germany, information about the personality of beach volleyball players from other countries, cultures, or ethnicities may also need to be studied to verify our results.

Our findings are of great interest to sports psychology practitioners, coaches, and scouts. In order to work with high-performance athletes, knowledge about an individual's personality might help in creating a functional working-relationship. Existing research has shown that a coach-athlete relationship is more beneficial when both share similar personality characteristics (Jackson et al., 2011). Therefore, our findings might help coaches to better understand their players' personality, beliefs as well as values, and consequently choose a suitable coaching-style, which helps prevent and/or solve conflicts. Coaches should also encourage their players to explore their own and their teammate's personality in order to gain better understanding of their team dynamics. Applied sports psychologists can support this process and provide knowledge about conflict resolution strategies and encourage self-esteem and self-acceptance.

Sports psychologists can also help in developing and strengthening emotion regulation strategies. As our sample showed, emotion regulation strategies were already well established. However, young athletes might not have developed enough strategies to deal with their own emotions. In summary, our research emphasizes on the importance of recognizing (beach volleyball) athletes' personalities and emotion regulation strategies in order to create competitive dyads in team sports.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the second author, without undue reservation, to any qualified researcher.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by German Sport University Cologne. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SK and BN developed the study concept and contributed to the design. SW collected the data. L-MR analyzed the data and wrote the first draft of the manuscript. All authors helped to edit and revised the manuscript and approved the final submitted version of the manuscript.

REFERENCES

Allen, M. S., Greenlees, I., and Jones, M. (2011). An investigation of the five-factor model of personality and coping behaviour in sport. *J. Sports Sci.* 29, 841–850. doi: 10.1080/02640414.2011.565064

Allen, M. S., Greenlees, I., and Jones, M. (2013). Personality in sport: a comprehensive review. *Int. Rev. Sport Exerc. Psychol.* 6, 184–208. doi: 10.1080/1750984x.2013.769614

Allen, M. S., and Laborde, S. (2014). The role of personality in sport and physical activity. *Curr. Dir. Psychol. Sci.* 23, 460–465. doi: 10.1177/0963721414550705

Allport, G. W. (1937). *Personality: a Psychological Interpretation*. United States: American Psychological Association.

Álvarez-Kurogi, L., Onetti, W., Fernández-García, J. C., and Castillo-Rodríguez, A. (2019). Does the psychological profile influence the position of promising young futsal players? *PLoS One* 14:e0224326. doi: 10.1371/journal.pone.0224326

Barańczuk, U. (2019). The five factor model of personality and emotion regulation: a meta-analysis. *Pers. Individ. Diff.* 139, 217–227. doi: 10.1016/j.paid.2018.11.025

Becker, H., and Useem, R. H. (1942). Sociological analysis of the dyad. *Am. Sociol. Rev.* 7:13. doi: 10.2307/2086253

Beebe, S. A., and Masterson, J. T. (2010). *Communicating in Small Groups: principles and Practices* 10th Edn. United States: Allyn & Bacon.

Berger, B. G., Weinberg, R. S., and Eklund, R. C. (2015). *Foundations of Exercise Psychology (Third edition)*. United States: FiT Publishing

Bourbousson, J., Poizat, G., Saury, J., and Seve, C. (2010). Team coordination in basketball: description of the cognitive connections among teammates. *J. Appl. Sport Psychol.* 22, 150–166. doi: 10.1080/10413201003664657

Boyle, G. J., Matthews, G., and Saklofske, D. H. (2008). *Personality Theories and Models: an Overview*. United States: Sage Publications, Inc.

Brandstätter, H. (2009). *Persönlichkeits-adjektiv-skalen (pask5). Fünf Faktoren Modell [Personality Adjective Scales—pask 5. Five Factor Model]*. Bonn: GESIS.

Brandwein, D., Watson, D., and Osman, Y. (2021). "Emotion regulation and dysregulation in athletes: intrapersonal and interpersonal dimensions" in *The Routledge Handbook of Clinical Sport Psychology*. eds D. R. Marks, A. T. Wolanin, and K. M. Shortway (United Kingdom: Routledge). 95–106. doi: 10.4324/9780429330971-10

Budak, G., Kara, İ., İç, Y. T., and Kasımbeyli, R. (2018). Optimization of harmony in team formation problem for sports clubs: a real-life volleyball team application. *Int. J. Appl. Sci. Eng.* 8:2.

Cameron, J. E., Cameron, J. M., Dithurbide, L., and Lalonde, R. N. (2012). Personality traits and stereotypes associated with ice hockey positions. *J. Sport Behav.* 35, 109–124.

Campbell-Sills, L., Barlow, D. H., Brown, T. A., and Hofmann, S. G. (2006). Effects of suppression and acceptance on emotional responses of individuals with anxiety and mood disorders. *Behav. Res. Ther.* 44, 1251–1263. doi: 10.1016/j.brat.2005.10.001

Campo, M., Sanchez, X., Ferrand, C., Rosnet, E., Friesen, A., and Lane, A. M. (2017). Interpersonal emotion regulation in team sport: mechanisms and reasons to regulate teammates' emotions examined. *Int. J. Sport Exerc. Psychol.* 15, 379–394. doi: 10.1080/1612197X.2015.1114501

Carron, A. V., Bray, S. R., and Eys, M. A. (2002). Team cohesion and team success in sport. *J. Sports Sci.* 20, 119–126. doi: 10.1080/026404102317200828

Carron, A. V., and Spink, K. S. (1995). The group size-cohesion relationship in minimal groups. *Small Group Res.* 26, 86–105. doi: 10.1177/1046496495261005

Cattell, H. E. P., and Mead, A. D. (2008). The sixteen personality factor questionnaire (16pf). *Sage Handb. Pers. Theor. Assess.* 2, 135–178. doi: 10.4135/9781849200479.n7

Cattell, R. B. (1943). The description of personality: basic traits resolved into clusters. *J. Abnorm. Soc. Psychol.* 38:476. doi: 10.1037/h0054116

Cattell, R. B. (1973). *Personality and Mood by Questionnaire*. New York: Jossey Bass.

Costa, P. T., and McCrae, R. R. (1992a). Four ways five factors are basic. *Personality and Individual Differences* 13, 653–665. doi: 10.1016/0191-8869(92)90236-I

Costa, P. T., and McCrae, R. R. (1992b). *Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) manual*. Odessa: Psychological Assessment Resources.

Dadelo, S., Turskis, Z., Zavadskas, E. K., and Dadeliene, R. (2014). Multi-criteria assessment and ranking system of sport team formation based on objective-measured values of criteria set. *Exp. Syst. Appl.* 41, 6106–6113. doi: 10.1016/j.eswa.2014.03.036

Eagleton, J. R., McKelvie, S. J., and de Man, A. (2007). Extraversion and neuroticism in team sport participants, individual sport participants, and nonparticipants. *Perc. Motor Skills* 105, 265–275. doi: 10.2466/pms.105.5.265-275

Ellis, A., Abrams, M., and Abrams, L. (2009). *Personality Theories: critical Perspectives*. United States: SAGE Publications.

Eysenck, H. J. (1957). *The Dynamics of Anxiety and Hysteria*. London: Routledge & Kegan Paul.

Eysenck, H. J. (1967). *The Biological Basis of Personality*. United States: American Psychological Association.

Fasold, F., Inzenhofer, V., Lingner, K., Noël, B., and Klatt, S. (2020). Personality traits of handball goalkeepers. *J. Hum. Sport Exerc.* 15, 283–293. doi: 10.14198/jhse.2020.152.04

Fasold, F., Nicklas, A., Seifriz, F., Schul, K., Noël, B., Aschendorf, P., et al. (2021). Gaze coordination of groups in dynamic events - A tool to facilitate analyses of simultaneous gazes within a team. *Front. Psychol.* 12:656388. doi: 10.3389/fpsyg.2021.656388

Fasold, F., Noël, B., Wolf, F., and Hüttermann, S. (2019). Coordinated gaze behaviour of handball referees - A practical exploration with focus on the methodical implementation. *Movement Sport Sci.* 102, 71–79. doi: 10.1051/sm/2018029

Fédération Internationale de Volleyball [FIVB] (2016). *Official Beach Volleyball Rules 2017 - 2020: approved by the 35th FIVB Congress 2016*. Switzerland: Fédération Internationale de Volleyball

Forsyth, D. R. (2014). *Group Dynamics* 6th Edn. Boston: Wadsworth/Cengage Learning.

Gilley, J. W., Morris, M. L., Waite, A. M., Coates, T., and Veliquette, A. (2010). Integrated theoretical model for building effective teams. *Adv. Dev. Hum. Resour.* 12, 7–28. doi: 10.1177/1523422310365309

Goldberg, L. R. (1990). An alternative "description of personality": the big-five factor structure. *J. Pers. Soc. Psychol.* 59, 1216–1229. doi: 10.1037//0022-3514.59.6.1216

Graser, J., Bohn, C., Kelava, A., Schreiber, F., Hofmann, S. G., and Stangier, U. (2012). Der „affective style questionnaire (asq)": deutsche adaption und validitäten. *Diagnostica* 58, 100–111.

Gross, J. J., and John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *J. Pers. Soc. Psychol.* 85:348. doi: 10.1037/0022-3514.85.2.348

Gyomber, N., Kovacs, K., and Lenart, A. (2016). Do psychological factors play a crucial role in sport performance? – Research on personality and psychological variables of athletes in Hungary. *Cuadernos de Psicol. Deport.* 16, 223–232.

Halfhill, T., Sundstrom, E., Lahner, J., Calderone, W., and Nielsen, T. M. (2005). Group personality composition and group effectiveness: an integrative review of empirical research. *Small Group Res.* 36, 83–105. doi: 10.1177/1046496404268538

Hervé, A. (2007). "The bonferonni and šidák corrections for multiple comparisons" in *Encyclopedia of Measurement and Statistics* ed. N. J. Salkind (United States: Sage). 103–107.

Hofmann, S. G., and Kashdan, T. B. (2010). The affective style questionnaire: development and psychometric properties. *J. Psychopathol. Behav. Assess.* 32, 255–263. doi: 10.1007/s10862-009-9142-4

Hüttermann, S., Noël, B., and Memmert, D. (2018). Eye tracking in high-performance sports: evaluation of its application in expert athletes. *Int. J. Comput. Sci. Sport* 17, 182–203. doi: 10.2478/ijcss-2018-0011

Jackson, B., Dimmock, J. A., Gucciardi, D. F., and Grove, J. R. (2010). Relationship commitment in athletic dyads: actor and partner effects for big five self- and other-ratings. *J. Res. Pers.* 44, 641–648. doi: 10.1016/j.jrp.2010.08.004

Jackson, B., Dimmock, J. A., Gucciardi, D. F., and Grove, J. R. (2011). Personality traits and relationship perceptions in coach–athlete dyads: do opposites really attract? *Psychol. Sport Exerc.* 12, 222–230. doi: 10.1016/j.psychsport.2010.11.005

Kashdan, T. B., and Steger, M. F. (2006). Expanding the topography of social anxiety: an experience-sampling assessment of positive emotions, positive events, and emotion suppression. *Psychol. Sci.* 17, 120–128. doi: 10.1111/j.1467-9280.2006.01674.x

Kirkcaldy, B. D. (1982). Personality and sex differences related to positions in team sports. *Int. J. Sport Psychol.* 13, 141–153.

Klatt, S., and Noël, B. (2020). Regulatory focus in sport revisited: does the exact wording of instructions really matter? *Sport Exerc. Perform. Psychol.* 9, 532–542. doi: 10.1037/spy0000195

Klatt, S., Noël, B., Nicklas, A., Schul, K., Seifriz, F., Schwarting, A., et al. (2021). Gaze behavior and positioning of referee teams during three-point shots in basketball. *Appl. Sci.* 11:6648. doi: 10.3390/app11146648

Klatt, S., and Smeeton, N. J. (2020). Visual and auditory information during decision making in sport. *J. Sport Exerc. Psychol.* 42, 15–25. doi: 10.1123/jsep.2019-0107

König-Görögh, D., Gyömbér, N., Szerdahelyi, Z., Laoues, N., Olvasztóné Balogh, Z., Tóth-Hosnyánszki, A., et al. (2017). Personality profiles of junior handball players: differences as a function of age, gender, and playing positions. *Cogn. Brain Behav. Interdiscipl. J.* 21, 237–247. doi: 10.24193/cbb.2017.21.15

Levine, J. M., and Moreland, R. L. (2012). "A history of small group research" in *Handbook of the History of Social Psychology*. (eds) A. W. Kruglanski and W. Stroebe (United States: Psychology Press). 382–404.

Mauss, I. B., Cook, C. L., Cheng, J. Y. J., and Gross, J. J. (2007). Individual differences in cognitive reappraisal: experiential and physiological responses to an anger provocation. *Int. J. Psychophysiol.* 66, 116–124. doi: 10.1016/j.ijpsycho.2007.03.017

Memmert, D., Plessner, H., Hüttermann, S., Froese, G., Peterhänsel, C., and Unkelbach, C. (2015). Collective fit increases team performances: extending regulatory fit from individuals to dyadic teams. *J. Appl. Soc. Psychol.* 45, 274–281. doi: 10.1111/jasp.12294

Mohammed, S., and Angell, L. C. (2003). Personality heterogeneity in teams. *Small Group Res.* 34, 651–677. doi: 10.1177/1046496403257228

Noël, B., Hüttermann, S., van der Kamp, J., and Memmert, D. (2016). Courting on the beach: how team position implicitly influences decision-making in beach volleyball serves. *J. Cogn. Psychol.* 28, 868–876. doi: 10.1080/20445911.2016.1194847

Piepiora, P. (2021). Assessment of personality traits influencing the performance of men in team sports in terms of the big five. *Front. Psychol.* 12:679724. doi: 10.3389/fpsyg.2021.679724

Rammstedt, B., and John, O. P. (2007). Measuring personality in one minute or less: a 10-item short version of the big five inventory in english and german. *J. Res. Pers.* 41, 203–212. doi: 10.1016/j.jrp.2006.02.001

Roberts, R., and Woodman, T. (2017). Personality and performance: moving beyond the big 5. *Curr. Opin. Psychol.* 16, 104–108. doi: 10.1016/j.copsyc.2017.03.033

Ryckman, R. M. (2012). *Theories of Personality* 10th Edn. United States: Cengage Learning.

Santos, R., Duarte, R., Davids, K., and Teoldo, I. (2018). Interpersonal coordination in soccer: interpreting literature to enhance the representativeness of task design, from dyads to teams. *Front. Psychol.* 9:2550. doi: 10.3389/fpsyg.2018.02550

Schurr, K. T., Ashley, M. A., and Joy, K. L. (1977). A multivariate analysis of male athlete personality characteristics: sport type and success. *Multivar. Exp. Clin. Res.* 3, 53–68.

Seligman, M. E. P., Steen, T. A., Park, N., and Peterson, C. (2005). Positive psychology progress: empirical validation of interventions. *Am. Psychol.* 60, 410–421. doi: 10.1037/0003-066X.60.5.410

Sherif, M. (1956). *An Outline of Social Psychology*. United States: Harper.

Trninić, S., Papić, V., Trninić, V., and Vukičević, D. (2008). Player selection procedures in team sports games. *Acta Kinesiol.* 2, 24–28.

Tuckman, B. W. (1965). Developmental sequence in small groups. *Psychol. Bull.* 63, 384–399. doi: 10.1037/h0022100

Uphill, M. A., Lane, A. M., and Jones, M. V. (2012). Emotion regulation questionnaire for use with athletes. *Psychol. Sport Exerc.* 13, 761–770. doi: 10.1016/j.psychsport.2012.05.001

Waleriańczyk, W., and Stolarski, M. (2021). Personality and sport performance: the role of perfectionism, big five traits, and anticipated performance in predicting the results of distance running competitions. *Pers. Individ. Diff.* 169:109993. doi: 10.1016/j.paid.2020.109993

Widmeyer, W. N., Brawley, L. R., and Carron, A. V. (1990). The Effects of Group Size in Sport. *J. Sport Exerc. Psychol.* 12, 177–190. doi: 10.1123/jsep.12.2.177

Woodman, T., Zourbanos, N., Hardy, L., Beattie, S., and McQuillan, A. (2010). Do performance strategies moderate the relationship between personality and training behaviors? An exploratory study. *J. Appl. Sport Psychol.* 22, 183–197. doi: 10.1080/10413201003664673

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

ORIGINAL RESEARCH
published: 02 November 2021
doi: 10.3389/fpsyg.2021.741756

Age-Related Differences in Hamstring Flexibility in Prepubertal Soccer Players: An Exploratory Cross-Sectional Study

Federico Abate Daga[1,2], Marco Panzolini[2], Ruben Allois[1,2], Luca Baseggio[2] and Samuel Agostino[2]*

[1] Department of Clinical and Biological Sciences, University of Turin, Turin, Italy, [2] School of Exercise and Sport Sciences, University of Turin, Turin, Italy

This study aimed to investigate the hamstring flexibility rate among prepubertal soccer players from U8 to U12 and the role of age and soccer years of practice on the course of hamstring flexibility. Six hundred eleven young Italian soccer players from a local soccer school in Turin were recruited for this research and assigned to each group according to their chronological age (U8 = 124 players; U9 = 130 players; U10 = 151 players; U11 = 89 players; and U12 = 120 players). Hamstring flexibility was measured using the Sit and Reach Test (SAR), while data analysis was run using a one-way analysis of variance (one-way ANOVA). Furthermore, Tuckey's *post hoc* was used to determine differences among the classes of age. Finally, a bivariate ordinal regression analysis was used to evaluate a potential association between age categories and hamstrings flexibility. In addition, multivariable ordinal regression was used to analyze this relationship adjusted for the Body Mass Index (BMI). The one-way ANOVA showed significant differences in flexibility among groups ($F = 32.76$, $P < 0.0001$). Tuckey's *post hoc* identified significant differences between U8 and U10 ($p < 0.01$; −2,39 cm of hamstring stretching), U8 and U11 ($p < 0.05$; −2.19 cm), U8 and U12 ($p < 0.0001$; −5.90), U9 and U12 ($p < 0.0001$; −4.98 cm), U10 and U12 ($p < 0.0001$; −3.5 cm), U11 and U12 ($p < 0,001$; −3.70 cm). In the bivariate ordinal regression analysis, there was a negative association between the age categories and hamstrings flexibility ($R^2 = 0.137$; $p < 0.0001$). The association persisted in multivariable ordinal regression analysis adjusted for BMI ($R^2 = 0.138$; $p < 0.0001$). This study underlines changes in hamstring flexibility across different age groups of prepubertal soccer players. The older and more experienced in soccer are less flexible than the younger, considering the hamstring muscles. Thus, appropriate stretching protocols should be included in prepubertal soccer training to avoid the risk of lead players to excess hamstring tightness.

Keywords: biological maturation, muscles flexibility, stretching, youth soccer, kids

OPEN ACCESS

Edited by:
Filipe Manuel Clemente, Polytechnic Institute of Viana do Castelo, Portugal

Reviewed by:
Mohamad Shariff Hamid, University of Malaya, Malaysia
Javier Sánchez-Sánchez, European University of Madrid, Spain

****Correspondence:***
Federico Abate Daga
federico.abatedaga@unito.it

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *15 July 2021*
Accepted: *07 October 2021*
Published: *02 November 2021*

Citation:
Abate Daga F, Panzolini M, Allois R, Baseggio L and Agostino S (2021) Age-Related Differences in Hamstring Flexibility in Prepubertal Soccer Players: An Exploratory Cross-Sectional Study. Front. Psychol. 12:741756. doi: 10.3389/fpsyg.2021.741756

INTRODUCTION

"Hamstrings" is a term commonly used to refer to the muscles biceps femoris, semitendinosus, and semimembranosus, which form prominent tendons medially and laterally at the back of the knee. The hamstrings have a prevalence of fast-twitch fibers, and their main action is the flexion of the knee. For this reason, these muscles play a crucial role in several team sports such as soccer, which requires a lot of running, sprinting, rapid changes of direction, and jumping (Turner et al., 2014). However, they are often subjected to injuries: (Cejudo et al., 2019) it is estimated that 28% of soccer players experience hamstrings injuries at some point in their career (Ekstrand et al., 2016), with a risk of subsequent injury risk of 12–31% (Pagare et al., 2014). Therefore, hamstrings' efficiency should be considered as a critical factor in soccer performance and injuries prevention (Le Gall et al., 2007; García-Pinillos et al., 2015; Medeiros et al., 2016). One essential characteristic of hamstring efficiency is flexibility (Medeiros et al., 2016), as it is a crucial quality in soccer performance, related to a lower incidence of injuries and a higher attendance to season matches (Witvrouw et al., 2003). Therefore, young soccer players' development plan should include strategies for optimal development of the hamstrings muscles (Mayorga-Vega et al., 2016). Hamstrings origin from the ischial tuberosity, and thus affect posture and spine alignment during growth; (Cini et al., 2017) for example, an excessive shortening of these muscles increases the tension on the pelvis and, consequently, may produce changes in the spine morphology (López-Miñarro et al., 2012). Therefore, hamstring flexibility training should be included in youth soccer training programs, as they tend to become tighter throughout the biological maturation, it is unclear whether this is due to physical growth or it is influenced by daily routine and practice (Zakas et al., 2002). Even if hamstring injuries occurred at a lower incidence in youth players than adults, a study conducted among 623 young players of Barcelona Football Club revealed an incidence of damage estimate at 0.041 for biceps femoris and 0.061 for semitendinosus and semimembranosus every 1,000 h of soccer practice (Valle et al., 2018). Furthermore, early specialization is considered a risk factor for hamstring injuries (Difiori et al., 2014; Read et al., 2016). Despite this, only a few articles investigated muscle flexibility in young soccer players (Nikolaïdis, 2012; Nikolaidis et al., 2014; Cejudo et al., 2019), and hamstrings flexibility training in youth football is a debated topic. Indeed, most of the studies are conducted in adults or post-pubertal players, and thus soccer school coaches do not have enough information to implement hamstring flexibility training in the youth. A general trend toward the flexibility reduction overages has been reported in non-athlete population (De Oliveira Medeiros et al., 2013) but, to date, this has not been explored in soccer. Therefore, the aim of this study is to investigate the age-related differences in hamstring flexibility in soccer school players.

MATERIALS AND METHODS

The study was conducted in September and October 2021, before the beginning of the regular season. Participants were recruited from a soccer academy in the city of Turin, Italy, from different categories: Under 8 (i.e., players from 6 to 7 years of age), Under 9 (i.e., players from 8 to 9 years of age), Under 10 (i.e., players from 9 to 10 years of age), Under 11 (i.e., players from 10 to 11 years of age), and Under 12 (i.e., players from 11 to 12 years of age). The inclusion criteria were: being outfield players regularly involved in soccer training (i.e., 2–3 training sessions and one match per week) and having at least 1 year of experience in soccer training. The exclusion criteria were: being involved in systematic and specific stretching training programs in the last 6 months, history of hamstring or low back injuries in the previous 3 months, playing as goalkeepers, and a BMI over the 95 percentiles of the referred age (i.e., U8:19.20 kg/m^2, U9: 19.77 kg/m^2, U10:20.88 kg/m^2, U11:22.06 kg/m^2, and U12:22.67 kg/m^2) (Weir and Jan, 2019; World Health Organization (WHO), 2020). This study was conducted in accordance with the Declaration of Helsinki and approved by the bioethical committee of the University of Turin, Italy (protocol number: 470603).

Testing Procedure

All subjects were evaluated at their training center. The players were evaluated on one of their training days immediately before starting the training session before warming up, as warm-up procedures might influence hamstring flexibility (O'Sullivan et al., 2009). Anthropometric measurements were performed at the beginning of the testing session. Body mass was measured to the nearest 0.1 kg (Innoliving, Ancona, Italy), with the participants wearing their football equipment except for shoes and shin guards, while standing height was measured to the nearest 0.01 meter with a wall stadiometer (Metrica 23119, San Donato Milanese, Italy). Body weight and standing height were used to calculate the body max index (BMI; BMI = kg/m^2).

The Sit and Reach Test (SAR) was performed with the subject sitting on the floor with his head, back, and hips against a wall, knees straight, legs together, and soles of the feet positioned flat against an SAR box (height: 30 cm, wide: 50 cm, and deep: 51 cm). The 0 cm mark of the measuring scale represented the starting point of the bar. The bar with the measuring scale was 80 cm long, running along the upper face of the SAR box. The place at which the feet contacted the box was 30 cm far from the starting point of the bar. The subject was required to extend the arms with palms down with index fingers in contact. Then, the subjects were asked to slowly bend forward to reach as far as possible while maintaining the knees extended and having their hands slide on the measuring scale placed on the box. The researcher should record the score and control that heels remained at the box and knees fully extended during the trial. Each player should perform only one attempt at their best. Allowing more than one attempt could convert a testing session into a flexibility training one. Therefore, only one try each player has admitted. The player was discharged and recalled to a new testing session on another training day in case of test failure. The SAR test is a straightforward way to investigate hamstring flexibility on large samples (Mayorga-Vega et al., 2014). Therefore, it was a functional test for this study.

Finally, to avoid the learning effect, all the soccer players completed a familiarization session to know the correct technical execution of the SAR test. Then, 1 week before the start of the study, each player tried to execute at least one time the SAR test.

Statistical Analysis

Descriptive statistics [mean and standard deviation (SD), median and interquartile range (IQR)] was used to present participants characteristics and study outcomes. Age-related differences in

TABLE 1 | Participants characteristics.

	Total (=611)	U8 (*n* = 124)	U9 (*n* = 130)	U10 (*n* = 151)	U11 (=86)	U12 (=120)
Age (years) (mean ± SD)	9 ± 1.59	7 ± 1	8 ± 1	9 ± 1	10 ± 1	11 ± 1
Weight (kg) (mean ± SD)	32.32 ± 7.29	26.27 ± 3.90	29.49 ± 5.88	34.54 ± 6.32	36.27 ± 5.78	39.12 ± 7.54
Height (cm) (mean ± SD)	135.51 ± 9.4	125.92 ± 5.52	132.87 ± 8.84	137.51 ± 5.88	140.9 ± 6.09	147.34 ± 6.03
BMI* (kg/m^2) (mean ± SD)	17.47 ± 2.34	16.53 ± 1.70	16.89 ± 2.22	18.16 ± 2.5	18.17 ± 2.22	17.93 ± 2.55
Sit&Reach (mean ± SD)	28.63 ± 5.79	30.52 ± 5.30	30.00 ± 5.17	28.13 ± 5.56	28.34 ± 6.58	24.63 ± 5.15
	U8 (*n* = 124)	**U9 (*n* = 130)**	**U10 (*n* = 151)**	**U11 (=86)**	**U12 (=120)**	**Total**
Age (years) (median)	7.00	8.00	9.00	10.00	11.00	9.00
Weight (kg) Median (IQR)	26.0 (4)	28.0 (6)	34.0 (9)	35.50 (8.25)	39.0 (8)	31.0 (10)
Height (cm) Median (IQR)	126.0 (7)	132.0 (8)	138.0 (7)	141.0 (9)	148.0 (8.5)	135.0 (12)
BMI* (kg/m2) Median (IQR)	16.08 (1.82)	16.28 (2.52)	17.82 (3.40)	17.74 (3.33)	17.6 (3.06)	16.89 (2.87)

Data are represented as mean ± standard deviation (SD) in the first part. On the opposite, in the second part, data are described as Median and Interquartile Range (IQR).
**BMI, Body Mass Index.*

hamstring flexibility were investigated using a univariate analysis of variance (ANOVA) with Tuckey's *post hoc*. The significance level was set at $\alpha = 0.05$. Bivariate ordinal regression analysis was used to evaluate a potential association between age and hamstrings flexibility. Multivariable ordinal regression was used to analyze the relationship between age and hamstrings flexibility adjusted for the Body Mass Index (BMI). R-Squared and associated *p*-values were reported for bivariate and multivariable analyses. All statistical analyses were conducted using SPSS Statistics (version 19.0; IBM Corp., Armonk, NY, United States).

RESULTS

Six hundred eleven from five age categories (U8 = 124 players, height: 125.92 ± 5.52 cm, weight: 26.27 ± 3.90 kg, BMI: 16.53 ± 1.70 kg/m^2, years of soccer school: 2 ± 1; U9 = 130 players, height 132.87 ± 8.84 cm, weight 29.49 ± 5.88 kg, BMI 16.89 ± 2.22 kg/m^2, years of soccer school: 3 ± 1; U10 = 151 players, height 137.51 ± 5.88 cm, weight 34.54 ± 6.32 kg, BMI 18.16 ± 2.50 kg/m^2, years of soccer school 4 ± 1; U11 = 89 players, height 140.90 ± 6.09 cm, weight 36.27 ± 5.78 kg, BMI 18.17 ± 2.22 kg/m^2, years of soccer school: 5 ± 1; and U12 = 120 players, height 147.34 ± 6.09 cm, weight 39.12 ± 7.54 kg, BMI 17.93 ± 2.55 kg/m^2, years of soccer school 6 ± 1) were enrolled in this study. The characteristics of the participants are presented in the **Table 1**. Sit and reach scores were: U8: 30.0 ± 5.4 cm, U9: 29.3 ± 5.5 cm, U10: 28.1 ± 5.6, U11: 28.3 ± 6.6, and U12: 24.4 ± 5.5 (**Table 1**). We observed statistically-significant differences in the SAR across the age groups: U8–U10 ($p < 0.01$, −2.4 cm), U8–U11 ($p < 0.05$, −2.2 cm), U8–U12 ($p < 0.0001$, −5.9 cm), U9–U12 ($p < 0.0001$, −5.0), U10–U12 ($p < 0.0001$, −3.5 cm), and U11–U12 ($p < 0.001$, −3.7 cm) (**Table 2** and **Figure 1**). The bivariate regression model revealed a negative association between the age categories and hamstrings flexibility ($b = -1.405$, $R^2 = 0.137$, $p < 0.0001$), and the association persisted if the model is adjusted for BMI ($R^2 = 0.138$; $p < 0.0001$) (**Table 3**).

DISCUSSION

The present study shows that players of the U8 had the best performance in the SAR, while the U12 had the lowest performance. In addition, a reduction in hamstring flexibility of approximately 4 cm was detected between U11 and U12

TABLE 2 | Description of the Tuckey's *post hoc* performed among classes of age.

Tuckey's *post hoc* among age categories			
		Mean difference (cm)	**95% CI**
U8	U9	0.91	(−0.99 to 2.81)
	U10	2.39**	(0.55 to 4.23)
	U11	2.19*	(0.06 to 4.31)
	U12	5.89*	(3.57 to 8.22)
U9	U10	148	(−0.33 to 3.30)
	U11	128	(−0.83 to 3.39)
	U12	4.99**	(2.68 to 7.29)
U10	U11	−0.21	(−2.25 to 1.84)
	U12	3.50**	(1.25 to 5.75)
U11	U12	3.71**	(1.21 to 6.19)

**p < 0.05; **p < 0.001.*

TABLE 3 | Representation of the bivariate (MODEL 1) and multivariable (MODEL 2) ordinal regression.

MODEL 1							MODEL 2						
			95% CI							95% CI			
	b	Beta coefficient	Lower	Upper	p	t		b	Beta coefficient	Lower	Upper	p	t
	40.786		38.22	43.35	< 0.001	31.232		41.80		38.19	45.40	< 0.001	22.765
AGE	−1.405	−0.370	−1.686	−1.125	< 0.001	−9.832	AGE	−1.37	−0.361	−1.664	−1.075	< 0.001	−9.133
BMI	–	–	–	–	–	–	BMI	−0.076	−0.031	−0.265	0.114	0.432	−0.786
R squared	0.137						R squared	0.138					

In the multivariable ordinal regression. BMI did not affect the association between age categories and hamstrings flexibility.

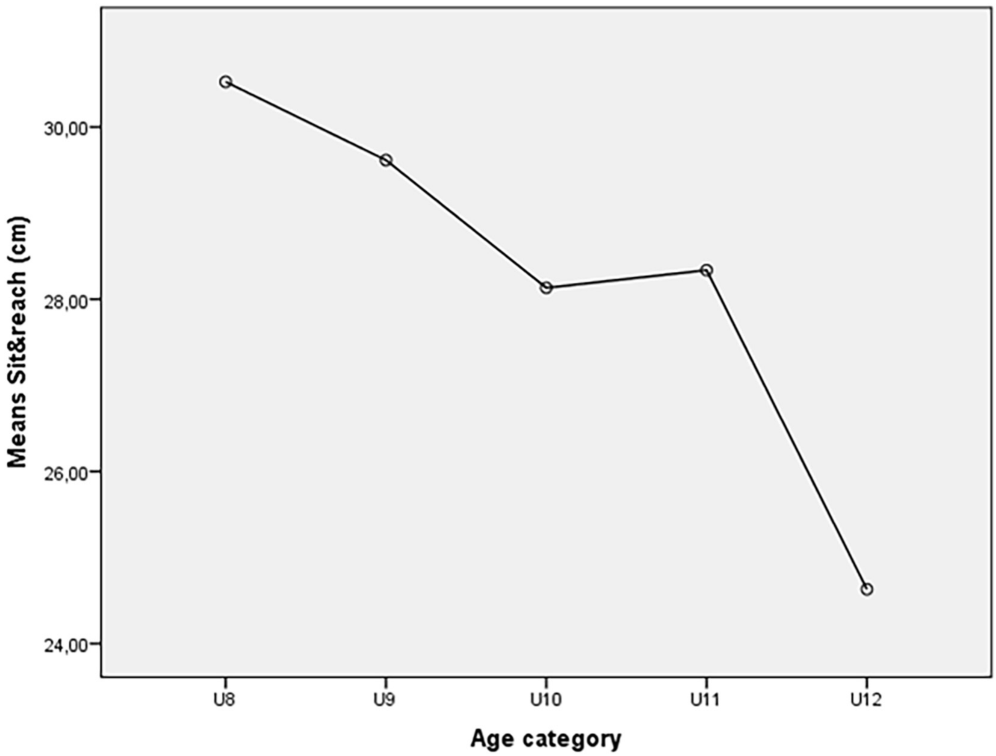


FIGURE 1 | Representation of hamstring flexibility decrease across age. The most significant hamstring flexibility decline is between U11 and U12.

players. Conversely, only 2 cm of hamstring flexibility reduction were identified between U8 (the youngest) and U11. The changes in hamstring flexibility seem to confirm that hamstring flexibility decreases with age (De Oliveira Medeiros et al., 2013; McKay et al., 2017).

Previous studies suggested that the decrease in hamstring flexibility with age can be due to biological changes, such as tendon stiffening, joint capsule changes, or muscle changes (Adams et al., 1999). Furthermore, it was demonstrated as tendon stiffening increases after resistance or power training (Seynnes et al., 2009). Thus, considering that repeated sprints, changes of directions, jumps, landing after jumping, or sudden deceleration from sprints characterizes soccer, it might be possible that these activities generate an early decrease of hamstring flexibility. Our outcomes seem to confirm this hypothesis underlining as hamstring flexibility is reduced across ages still from pre-puberty.

On the opposite, hamstring flexibility was established as a critical factor for soccer performance in adults (Witvrouw et al., 2003) and youth (García-Pinillos et al., 2015). In fact, specific drills such as sprinting, jumping, agility, and kicking require good levels of hamstring flexibility to be efficient (García-Pinillos et al., 2015). Thus, considering its implication in soccer performance, flexibility training should not be underestimated from soccer school.

Moreover, the consistent significant difference in flexibility reduction detected from U11 to U12 is essential for this paper and should be evidenced. This stage is a sort of transition from childhood to puberty, where structural and physiological changes appear. The period between 12/13 and 15 years old corresponds to the Peak of Heigh Velocity (PHV). In this stage, the skeleton overgrows compared to muscles and tendons (Rumpf and Cronin, 2012). Therefore, muscle tightness rapidly increases, particularly around joints (Le Gall et al., 2007). This research evidenced a reduction of 4 cm in hamstrings flexibility from U11 to U12, certifying a double increase of hamstrings tightness compared with the one detected from U8 to U11, where all the players were still in the childhood stage. Thus, puberty might create an excess of hamstring tightness in soccer players that could be dangerous for muscle health, skill acquisition, and soccer performance.

This research identified an association between hamstring flexibility decrease and age categories, and this model explains the 14% variance. The remaining 86% could not be presented with the association between age categories and hamstrings flexibility reduction and might be related to other factors. For example, decreased hamstring flexibility could be due to altered neuro-dynamics (Kornberg and Lew, 1989), joint structure, viscoelastic properties, cross-sectional area, stretch tolerance (Magnusson et al., 1997), and type of training (Klinge et al., 1997). However, even if the effect is small, coaches, and team staff should carefully consider this association between age categories and hamstrings flexibility when setting soccer school training.

Last but not least, this study reveals some strengths and limitations. First of all, this study involved a large number of participants. A large sample usually guarantees more powerful findings. Therefore, the final message is commonly more robust. Furthermore, a quick and straightforward test like Sit and Reach is an efficient solution to screen a significant number of participants efficiently. However, on the other hand, such a considerable number of participants may lead to some limits. One of them may be identified in the impossibility of thoroughly assessing the lower back health before the evaluation. However, the hamstring flexibility assessment was performed using the SAR to repair this condition partially.

In addition, pelvis and spine mobility plays a crucial role in posterior chain flexibility assessment. High values of the pelvis and spine mobility can influence the hamstrings flexibility scores. However, this situation can be mechanically excluded from bending the upper body while seated. Thus, hamstring flexibility scores using SAR are not influenced by spine and pelvis mobility, and findings are more connected to muscle stretching potential. Secondly, physical growth may be another limitation of this research. Early or late maturation may affect muscles flexibility scores. In this research, no thorough assessment of physical growth was performed. As previously declared, large sample size is difficult to assess entirely due to logistics and practical organization. However, the inclusion criteria of this study indicated that only participants whose BMI did not exceed the 95th percentile of the referred age were eligible for this study. Therefore, findings were not affected by very early physical growth or obesity. This fact partially mitigates the limit of no physical growth assessment. Finally, future researches should investigate hamstring flexibility throughout an entire soccer season to analyze the impact of continuative soccer training on hamstring flexibility changes.

CONCLUSION

In conclusion, this study highlighted the crucial difference in the hamstring flexibility measurement among prepubertal male soccer players of different ages. In addition, players of the older age category have lesser hamstring flexibility measurement compared to younger ones. Thus, hamstring tightness is highly enhanced in players belonging to the U12. Therefore, hamstring flexibility schedules must be empowered in the so-called "pubertal stage" to avoid the risk of hamstring injuries exposure during biological maturation.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Turin Bioethical Committee (Comiato bioetico di Ateneo), University of Turin, Turin, Italy. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

FA contributed to the manuscript's conception and design and supervised the experimental phase. SA, LB, and MP conducted the experiment, performed the calculations, and organized the tables and graphs. FA wrote the manuscript with input from all authors. All authors read and approved the final version of the manuscript. Finally, RA assisted all authors during the manuscript writing and observed reviewer's recommendations and manuscript modification.

ACKNOWLEDGMENTS

The authors want to dedicate this manuscript to the memory of Massimiliano Gollin, an important mentor and a dear friend for all of us.

REFERENCES

Adams, K., O'Shea, P., and O'Shea, K. L. (1999). Aging: its effects on strength, power, flexibility, and bone density. *Natl. Strength Condition. Assoc.* 21, 65–77. doi: 10.1519/1533-42951999021<0065:aieosp<2.0.co;2

Cejudo, A., Robles-Palazón, F. J., Ayala, F., De Ste Croix, M., Ortega-Toro, E., Santonja-Medina, F., et al. (2019). Age-related differences in flexibility in soccer players 8-19 years old. *PeerJ* 2019, 1–16. doi: 10.7717/peerj.6236

Cini, A., De Vasconcelos, G. S., and Lima, C. S. (2017). Acute effect of different time periods of passive static stretching on the hamstring flexibility. *J. Back Musculoskelet. Rehabil.* 30, 241–246. doi: 10.3233/BMR-160740

De Oliveira Medeiros, H. B., De Araújo, D. S. M. S., and De Araújo, C. G. S. (2013). Age-related mobility loss is joint-specific: an analysis from 6,000 Flexitest results. *Age* 35, 2399–2407. doi: 10.1007/s11357-013-9525-z

Difiori, J. P., Benjamin, H. J., Brenner, J. S., Gregory, A., Jayanthi, N., Landry, G. L., et al. (2014). Overuse injuries and burnout in youth sports: a position statement from the American medical society for sports medicine. *Br. J. Sports Med.* 48, 287–288. doi: 10.1136/bjsports-2013-093299

Ekstrand, J., Waldén, M., and Hägglund, M. (2016). Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13-year longitudinal analysis of the UEFA Elite Club injury study. *Br. J. Sports Med.* 50, 731–737. doi: 10.1136/bjsports-2015-095359

García-Pinillos, F., Ruiz-Ariza, A., Moreno del Castillo, R., and Latorre-Román, P. (2015). Impact of limited hamstring flexibility on vertical jump, kicking speed, sprint, and agility in young football players. *J. Sports Sci.* 33, 1293–1297. doi: 10.1080/02640414.2015.1022577

Klinge, K., Magnusson, S. P., Simonsen, E. B., Aagaard, P., Klausen, K., and Kjaer, M. (1997). The effect of strength and flexibility training on skeletal muscle electromyographic activity, stiffness, and viscoelastic stress relaxation response. *Am. J. Sports Med.* 25, 710–716. doi: 10.1177/036354659702500522

Kornberg, C., and Lew, P. (1989). The effect of stretching neural structures on grade one hamstring injuries. *J. Orthopaedic Sports Phys. Ther.* 10, 481–487. doi: 10.2519/jospt.1989.10.12.481

Le Gall, F., Carling, C., and Reilly, T. (2007). Biological maturity and injury in elite youth football. *Scand. J. Med. Sci. Sports* 17, 564–572. doi: 10.1111/j.1600-0838.2006.00594.x

López-Miñarro, P. A., Muyor, J., Belmonte, F., and Alacid, F. (2012). Acute effects of hamstring stretching on sagittal spinal curvatures and pelvic tilt. *J. Hum. Kinet.* 31, 69–78. doi: 10.2478/v10078-012-0007-7

Magnusson, S. P., Simonsen, E. B., Aagaard, P., Boesen, J., Johannsen, F., and Kjaer, M. (1997). Determinants of musculoskeletal flexibility: viscoelastic properties. cross-sectional area, EMG and stretch tolerance. *Scand. J. Med. Sci. Sports* 7, 195–202. doi: 10.1111/j.1600-0838.1997.tb00139.x

Mayorga-Vega, D., Merino-Marban, R., and Viciana, J. (2014). Criterion-related validity of sit-and-reach tests for estimating hamstring and lumbar extensibility: a meta-analysis. *J. Sports Sci. Med.* 13, 1–14.

Mayorga-Vega, D., Merino-Marban, R., Manzano-Lagunas, J., Blanco, H., and Viciana, J. (2016). Effects of a stretching development and maintenance program on hamstring extensibility in schoolchildren: a cluster-randomized controlled trial. *J. Sports Sci. Med.* 15, 65–74.

McKay, M. J., Baldwin, J. N., Ferreira, P., Simic, M., Vanicek, N., Burns, J., et al. (2017). Normative reference values for strength and flexibility of 1,000 children and adults. *Neurology* 88, 36–43. doi: 10.1212/WNL.0000000000003466

Medeiros, D. M., Cini, A., Sbruzzi, G., and Lima, C. S. (2016). Influence of static stretching on hamstring flexibility in healthy young adults: systematic review and meta-analysis. *Physiother. Theory Pract.* 32, 438–445. doi: 10.1080/09593985.2016.1204401

Nikolaïdis, P. (2012). Age-related differences of hamstring flexibility in male soccer players. *Baltic J. Health Phys. Activity* 4, 110–115. doi: 10.2478/v10131-012-0012-1

Nikolaidis, P., Ziv, G., Lidor, R., and Arnon, M. (2014). Inter-individual variability in soccer players of different age groups playing different positions. *J. Hum. Kinet.* 40, 213–225. doi: 10.2478/hukin-2014-0023

O'Sullivan, K., Murray, E., and Sainsbury, D. (2009). The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects. *BMC Musculoskelet. Disord.* 10:37. doi: 10.1186/1471-2474-10-37

Pagare, V. K., Ganacharya, P. M., Sareen, A., and Palekar, T. J. (2014). Effect of neurodynamic sliding technique versus static stretching on hamstring flexibility in football players with short hamstring syndrome. *J. Musculoskelet. Res.* 17, 1–8. doi: 10.1142/S0218957714500092

Read, P. J., Oliver, J. L., De Ste Croix, M. B. A., Myer, G. D., and Lloyd, R. S. (2016). The scientific foundations and associated injury risks of early soccer specialization. *J. Sports Sci.* 34, 2295–2302. doi: 10.1080/02640414.2016.1173221

Rumpf, M. C., and Cronin, J. (2012). Injury incidence, body site, and severity in soccer players aged 6-18 years: implications for injury prevention. *Strength Condition. J.* 34, 20–31. doi: 10.1519/SSC.0b013e31821a9833

Seynnes, O. R., Erskine, R. M., Maganaris, C. N., Longo, S., Simoneau, E. M., Grosset, J. F., et al. (2009). Training-induced changes in structural and mechanical properties of the patellar tendon are related to muscle hypertrophy but not to strength gains. *J. Appl. Physiol.* 107, 523–530. doi: 10.1152/japplphysiol.00213.2009

Turner, A. N., Cree, J., Comfort, P., Jones, L., Chavda, S., Bishop, C., et al. (2014). Hamstring strain prevention in elite soccer players. *Strength Condition. J.* 36, 10–20. doi: 10.1519/SSC.0000000000000076

Valle, X., Malliaropoulos, N., Párraga Botero, J. D., Bikos, G., Pruna, R., Mónaco, M., et al. (2018). Hamstring and other thigh injuries in children and young athletes. *Scand. J. Med. Sci. Sports* 28, 2630–2637. doi: 10.1111/sms.13282

Weir, C. B., and Jan, A. (2019). *BMI Classification Percentile and Cut Off Points*. Treasure Island, FL: StatPearls Publishing.

Witvrouw, E., Danneels, L., Asselman, P., D'Have, T., and Cambier, D. (2003). Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players: a prospective study. *Am. J. Sports Med.* 31, 41–46. doi: 10.1177/03635465030310011801

World Health Organization (WHO) (2020). *Rational Use of Personal Protective Equipment for Coronavirus Disease 2019 (COVID-19): Interim Guidance. 6 April 2020. WHO. 2019(6 April). 1–7*. Geneva: WHO.

Zakas, A., Galazoulas, C., Grammatikopoulou, M. G., and Vergou, A. (2002). Effects of stretching exercise during strength training in prepubertal, pubertal and adolescent boys. *J. Bodywork Mov. Ther.* 6, 170–176. doi: 10.1054/jbmt.2001.0275

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

ORIGINAL RESEARCH
published: 29 November 2021
doi: 10.3389/fpsyg.2021.729247

Development and Validation of Prediction Formula of Wingate Test Peak Power From Force–Velocity Test in Male Soccer Players

Pantelis T. Nikolaidis[1,2] ***and Beat Knechtle***[3]*

[1] *School of Health and Caring Sciences, University of West Attica, Athens, Greece,* [2] *Exercise Physiology Laboratory, Nikaia, Greece,* [3] *Institute of Primary Care, University of Zurich, Zurich, Switzerland*

Peak power of the Wingate anaerobic test (WAnT), either in W (Ppeak) or in $W.kg^{-1}$ (rPpeak), has been widely used to evaluate the performance of soccer players; however, its relationship with force–velocity (F-v) test (e.g., whether these tests can be used interchangeably) has received little scientific attention so far. The aim of this work was to develop and validate a prediction equation of Ppeak and rPpeak from F-v characteristics in male soccer players. Participants were 158 adult male soccer players (sport experience 11.4 ± 4.5 years, mean ± standard deviation, approximately five weekly training units, age 22.6 ± 3.9 years, body mass 74.8 ± 7.8 kg, and height 178.3 ± 7.8 cm) who performed both WAnT and F-v test. An experimental (EXP, $n = 79$) and a control group (CON, $n = 79$) were used for development and validation, respectively, of the prediction equation of Ppeak and rPpeak from F-v test. In EXP, Ppeak correlated very largely with body mass ($r = 0.787$), fat-free mass ($r = 0.765$), largely with maximal power of F-v test (P_{max}; $r = 0.639$), body mass index ($r = 0.603$), height ($r = 0.558$), moderately with theoretical maximal force (F_0; $r = 0.481$), percentage of body fat ($r = 0.471$), fat mass ($r = 0.443$, $p < 0.001$); rPpeak correlated with *rP*max (largely; $r = 0.596$, $p < 0.001$), theoretical maximal velocity (v_0; moderately; $r = 0.341$, $p = 0.002$), F_0 (small magnitude; $r = 0.280$, $p = 0.012$), BF ($r = -0.230$, $p = 0.042$), and fat mass ($r = -0.242$, $p = 0.032$). Ppeak in EXP could be predicted using the formula "44.251 + 7.431 × body mass (kg) + 0.576 × P_{max} (W) − 19.512 × F_0" ($R = 0.912$, $R^2 = 0.833$, standard error of estimate (SEE) = 42.616), and rPpeak from "3.148 + 0.218 × *rP*max ($W.kg^{-1}$) + v0 (rpm)" ($R = 0.765$, $R^2 = 0.585$, SEE = 0.514). Applying these formulas in CON, no bias was observed between the actual and the predicted Ppeak (mean difference 2.5 ± 49.8 W; 95% CI, −8.7, 13.6; $p = 0.661$) and rPpeak (mean difference 0.05 ± 0.71 $W.kg^{-1}$; 95% CI, −0.11, 0.21, $p = 0.525$). These findings provided indirect estimates of Ppeak of the WAnT, especially useful in periods when this test should not be applied considering the fatigue it causes; in this context, the F-v test can be considered as an alternative of exercise testing for estimating the average Ppeak of a group of soccer players rather than for predicting individual scores when the interindividual variation of performance is small.

Keywords: all-out test, anaerobic power, cycle ergometer, football, muscle strength, performance, speed

Edited by:
Miguel-Angel Gomez-Ruano, Polytechnic University of Madrid, Spain

Reviewed by:
Souhail Hermassi, Qatar University, Qatar
Vasileios T. Stavrou, University of Thessaly, Greece

****Correspondence:***
Beat Knechtle
beat.knechtle@hispeed.ch

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *22 June 2021*
Accepted: *01 November 2021*
Published: *29 November 2021*

Citation:
Nikolaidis PT and Knechtle B (2021) Development and Validation of Prediction Formula of Wingate Test Peak Power From Force–Velocity Test in Male Soccer Players. Front. Psychol. 12:729247. doi: 10.3389/fpsyg.2021.729247

INTRODUCTION

Performance in soccer has been shown to rely on movements such as sprinting, passing, shooting, jumping, and change of direction (Lepschy et al., 2021; Longo et al., 2021). Considering the short duration and maximal effort characterizing these movements, it was not surprising that the Wingate anaerobic test (WAnT), an all-out 30-s test on a cycle ergometer, was widely used to evaluate performance in this team sport (Chtourou et al., 2019; Bahenský et al., 2020). The most popular index of the WAnT has been the peak power expressed either in absolute (Ppeak) or relative to body mass values (rPpeak). Ppeak was related largely with linear and non-linear sprint performance and moderately with 20-m sprint performance, and could differentiate soccer players among playing positions (Joo and Seo, 2016; Nikolaidis et al., 2016; Almansba et al., 2019). Nevertheless, performing the WAnT might be contraindicated during congested fixture periods or periods of intense training (Freitas et al., 2021). In such periods, additional exercise testing fatigue would be undesirable considering that WAnT might lead to blood lactate concentration higher than 11 mmol.L^{-1} in soccer players (Keir et al., 2013; Thom et al., 2020) and athletes of other sport (Jemni et al., 2006), and the use of surrogate measures of short-term muscle power might be an alternative.

The force–velocity (F-v) test, eliciting maximal power either in W (*P*max) or W.kg^{-1} (*rP*max), was also performed on a cycle ergometer; however, compared to the WAnT that used 30-s continuous exercise, it lasted a similar total duration, but included a series of sprints separated by 5 min of recovery (Vandewalle et al., 1985; Aloui et al., 2020). The intermittent protocol of the F-v test might explain the relatively low post-test blood lactate values reported in the literature, e.g., 3.5 mmol.L^{-1} (Sanchez et al., 2012), ∼6.5 mmol.L^{-1} (Bouhlel et al., 2010), and ∼7.5 mmol.L^{-1} (Blonc et al., 1998). In addition to *P*max and *rP*max, the F-v test provided two other indices, namely theoretical maximal force (F_0) and velocity (v_0) (Jaafar, 2017). Moreover, the F-v test has been used less often than WAnT in the evaluation of soccer players (Ben Ayed et al., 2011; Hammami et al., 2019). In this context, considering the importance of short-term muscle power for soccer performance, it would be interesting to examine the relationship of *P*peak and *rP*peak of the WAnT with indices of the F-v test.

Although the abovementioned studies enhanced our understanding of the metabolic demands of the WAnT and F-v test, little information has been available about their relationship, and particularly, about the possibility to predict Ppeak and rPpeak from F-v characteristics (i.e., *P*max, *rP*max, F_0, and v_0). Such information would be of great practical use for coaches and trainers working with soccer players to monitor performance, especially during periods of intense training and competition; if the prediction of Ppeak and rPpeak from F-v characteristics was possible, the F-v test as a less "lactic" exercise test, and consequently, inducing less fatigue, could be an alternative to the WAnT for the evaluation of *P*peak and *rP*peak (Bouhlel et al., 2010; Keir et al., 2013). Therefore, the aim of this work was to (a) develop a prediction equation of *P*peak and *rP*peak in soccer players, (b) examine the validity of this equation and its variation by performance level of rPpeak. The research hypothesis was that the development and validation of prediction equations would be possible considering the affinity of the WAnT and F-v test in terms of metabolic demands and mode of motion (Driss and Vandewalle, 2013).

MATERIALS AND METHODS

Participants and Study Design

Participants were 158 adult men soccer players of soccer clubs of regional level (i.e., from the third, fourth, and fifth national league; sport experience 11.4 ± 4.5 years, mean ± standard deviation, approximately five weekly training units, age 22.6 ± 3.9 years, body mass 74.8 ± 7.8 kg, and height 178.3 ± 7.8 cm) who performed both WAnT and F-v test. An experimental (EXP, n = 79) and a control group (CON, n = 79) were used for the development and validation of prediction equation, respectively, of *P*peak and *rP*peak from F-v test. All participants provided informed consent after having been presented the benefits and risks of their participation in the present study.

Equipment and Protocols

A weight scale (HD-351 Tanita, Illinois, United States) measured body mass (in the nearest 0.1 kg), a portable stadiometer (SECA, Leicester, United Kingdom) height (0.1 cm), and a caliper (Harpenden, West Sussex, United Kingdom) skinfolds (0.5 mm), respectively. Body mass index (BMI) was calculated as the quotient of body mass (kg) to height squared (m^2). Body fat percentage (BF) was estimated from the sum of 10-skinfolds (cheek, wattle, chest I: pectoral, triceps, subscapular, abdominal, chest II: between the anterior axillary fold and the nipple, suprailiac, thigh and calf; $BF = -41.32 + 12.59 \times \log_e x$, where x is the sum of 10 skinfolds) (Eston and Reilly, 2009). Fat mass and fat-free mass were calculated using the formulas "body mass × BF/100′"and "body mass – fat mass," respectively. The F-v test was employed to assess *P*max, *rP*max, F_0, and v_0. This test employed various braking forces eliciting different pedaling velocities to evaluate the F-v relationship (Vandewalle et al., 1985; Aloui et al., 2020). The participants performed four sprints, each one lasting 7 s against incremental braking force (2, 3, 4, and 5 kg) on a cycle ergometer (Ergomedics 874, Monark, Sweden), interspersed by 5-min recovery periods. The WAnT was administered in the same ergometer as the F-v did (Dotan and Bar-Or, 1980; Miller, 2020). Briefly, participants were asked to pedal as fast as possible for 30 s against a braking force that was determined by the product of body mass in kilograms by 0.075. Both WAnT and F-v test have shown excellent intraclass correlation coefficient (>0.98) (Ingle and Tolfrey, 2013).

Statistical and Data Analysis

A one-way analysis of variance examined differences in training, anthropometric, and physiological characteristics in the total sample of participants among quintiles of *rP*peak, i.e., low (n = 32; minimum, 8.96 W.kg^{-1} maximum, 10.60 W.kg^{-1}), below

TABLE 1 | Training, anthropometric and physiological characteristics in the total sample of participants (*n* = 158) and by quintiles of relative peak power of the Wingate anaerobic test.

Variable	Total (*n* = 158)	Low *r*Ppeak (*n* = 32)	Below average *r*Ppeak (*n* = 31)	Average *r*Ppeak (*n* = 32)	Above average *r*Ppeak (*n* = 31)	High *r*Ppeak (*n* = 32)	*P*	η^2
Training and anthropometry								
Sport experience (years)	11.4 ± 4.5	12.5 ± 5.1	10.3 ± 4.7	11.3 ± 4.5	10.3 ± 4.5	12.1 ± 3.8	0.439	0.038
T.U. (number.wk^{-1})	4.8 ± 1.4	4.5 ± 1.1	5.2 ± 1.6	5.1 ± 1.2	4.6 ± 1.3	4.5 ± 1.7	0.282	0.043
Duration of T.U. (min)	91.3 ± 19.6	92.9 ± 12.2	90.0 ± 12.2	91.7 ± 20.1	94.4 ± 21.0	87.9 ± 26.0	0.800	0.014
Duration of training (min.wk^{-1})	454.5 ± 179.7	429.3 ± 128.3	471.7 ± 157.4	478.1 ± 176.3	453.4 ± 183.6	439.4 ± 230.5	0.303	0.011
Age (years)	22.6 ± 3.9	23.8 ± 4.6	21.3 ± 3.0	22.9 ± 4.2	22.4 ± 3.5	22.3 ± 3.4	0.133	0.045
Height (cm)	178.3 ± 7.8	176.6 ± 6.3	178.5 ± 5.8	179.7 ± 5.3	178.4 ± 6.3	178.3 ± 5.6	0.344	0.029
Body mass (kg)	74.8 ± 7.8	74.7 ± 11.2	76.2 ± 7.7	75.1 ± 6.7	74.3 ± 7.2	73.5 ± 5.1	0.738	0.013
BMI (kg.m^{-2})	23.5 ± 1.9	23.9 ± 2.8	23.9 ± 1.6	23.2 ± 1.7	23.3 ± 1.4	23.1 ± 1.5	0.296	0.031
BF (%)	15.8 ± 3.3	16.9 ± 4.1	16.2 ± 3.3	15.6 ± 3.0	15.0 ± 3.3	15.2 ± 2.3	0.153	0.043
Force-velocity test								
*P*max (W)	1129 ± 222	1017 ± 230	1105 ± 165	1129 ± 171	1187 ± 267	1207 ± 220	0.005	0.093
*r*Pmax (W.kg^{-1})	15.12 ± 2.66	13.66 ± 2.50	14.51 ± 1.74	15.05 ± 2.00	16.01 ± 3.34	16.38 ± 2.61	<0.001	0.140
v_0 (rpm)	220.3 ± 18.9	209.1 ± 22.4	213.9 ± 18.9	221.8 ± 15.2	224.8 ± 15.3	232.1 ± 12.8	<0.001	0.186
F_0 (kg)	20.74 ± 4.94	19.88 ± 5.89	20.89 ± 3.97	20.57 ± 4.00	21.42 ± 6.04	20.95 ± 4.58	0.800	0.011
Wingate anaerobic test								
Ppeak (W)	846.8 ± 101.9	752.4 ± 110.2	828.5 ± 87.4	862.2 ± 75.0	876.3 ± 85.4	914.7 ± 70.7	<0.001	0.293
rPpeak (W.kg^{-1})	11.33 ± 0.85	10.08 ± 0.41	10.91 ± 0.18	11.41 ± 0.12	11.80 ± 0.09	12.43 ± 0.36	<0.001	0.904
Pmean (W)	656.3 ± 72.7	596.6 ± 80.7	645.8 ± 60.7	669.4 ± 53.5	677.02 ± 72.5	693.0 ± 55.9	<0.001	0.214
rPmean (W.kg^{-1})	8.81 ± 0.78	8.02 ± 0.72	8.50 ± 0.61	8.95 ± 0.74	9.15 ± 0.44	9.44 ± 0.44	<0.001	0.409
FI (%)	43.29 ± 7.62	40.58 ± 9.47	42.35 ± 7.94	42.60 ± 7.80	44.49 ± 6.65	46.50 ± 4.34	0.026	0.071

Values were presented as mean ± standard deviation (SD). T.U. = training units; BMI = body mass index, BF = body fat percentage, Pmax = absolute maximal power, rPmax = relative maximal power, v_0 *= theoretical maximal velocity,* F_0 *= theoretical maximal force, Ppeak = absolute peak power, rPpeak = relative peak power, Pmean = absolute mean power, rPmean = relative mean power, FI = fatigue index.*

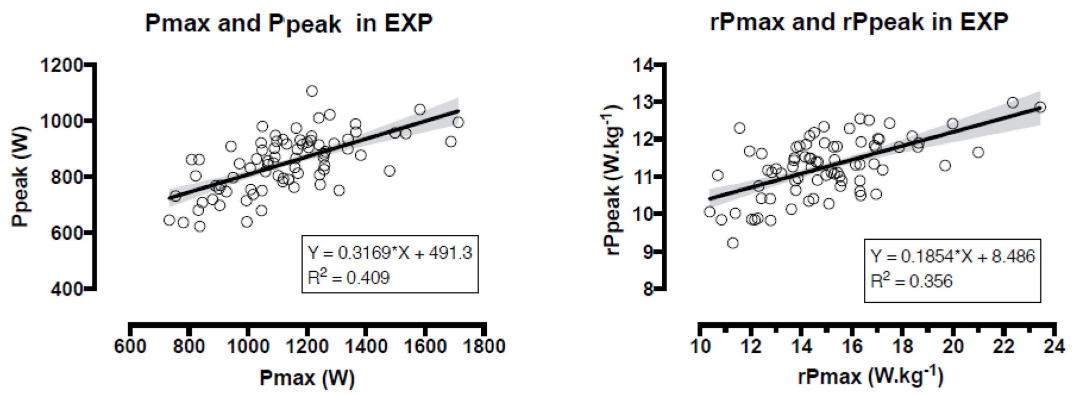


FIGURE 1 | Relationship between maximal power of the force-velocity test and peak power of the Wingate anaerobic test (both in absolute and relative to body mass values) in the experimental group. *P*max = absolute maximal power, *rP*max = relative maximal power, *P*peak = absolute peak power, *rP*peak = relative peak power.

average (n = 31; 10.61–11.18 W.kg^{-1}), average (n = 32; 11.21–11.62 W.kg^{-1}), above average (n = 31; 11.63–12.00 W.kg^{-1}) and high *rP*peak (n = 32; 12.02–13.78 W.kg^{-1}). The magnitude of these differences was evaluated by eta squared (η^2). An independent *t*-test compared training, anthropometric, and physiological characteristics between EXP (n = 79) and CON (n = 79), and 95% confidence intervals were calculated for potential differences. The magnitude of differences between EXP and CON was assessed by Cohen's *d*. In EXP, Pearson's moment correlation coefficient (r) examined the relationship of *P*peak and *rP*peak with anthropometric and F-v characteristics (cut-off of *r*: < 0.10, trivial; 0.10–0.30, small; 0.30–0.50, moderate; 0.50–0.70, large; 0.70–0.90 very large; >0.90, perfect relationship). Also, in EXP, a stepwise regression analysis was carried out to identify predictors and develop prediction equations of *P*peak and *rP*peak. In CON, Bland–Altman plots examined the agreement between predicted and actual *P*peak and *rP*peak. All analyses were performed using GraphPad Prism v. 7.0 (GraphPad Software, San Diego, CA, United States) and IBM SPSS v.26.0 (SPSS, Chicago, IL, United States). Statistical significance for these analyses was set at alpha = 0.05.

RESULTS

Performance groups (quintiles of rPpeak) did not differ for training ($p \geq 0.282$, $\eta^2 \leq 0.043$) and anthropometric characteristics ($p \geq 0.133$, $\eta^2 \leq 0.045$) (**Table 1**). In addition to *rP*peak, they also differed in *P*peak, *P*mean, *rP*mean and FI of the WAnT, and *P*max, *rP*max and v0 of the F-v test ($p \leq 0.026$, $\eta^2 \geq 0.071$), but not for F_0 ($p = 0.800$, $\eta^2 = 0.011$). Participants of high *rP*peak showed higher scores in the abovementioned variables than those with lower *rP*peak.

In EXP, Ppeak correlated very largely with body mass ($r = 0.787$), fat-free mass ($r = 0.782$), largely with *P*max ($r = 0.639$), BMI ($r = 0.603$), fat mass ($r = 0.611$) height ($r = 0.558$), moderately with F_0 ($r = 0.481$), BF ($r = 0.471$; $p < 0.001$), but not with *rP*max ($r = 0.190$, $p = 0.093$) age ($r = 0.189$, $p = 0.096$), and v_0 ($r = 0.128$, $p = 0.262$); *rP*peak correlated with *rP*max (largely; $r = 0.596$, $p < 0.001$), v_0 (moderately; $r = 0.341$, $p = 0.002$), F_0 (small magnitude; $r = 0.280$, $p = 0.012$), BF ($r = -0.230$, $p = 0.042$), fat mass ($r = -0.242$, $p = 0.032$). The correlations between Ppeak and *P*max, rPpeak and *rP*max in EXP are presented in **Figure 1**.

Compared with CON, EXP had similar sport experience (mean difference −0.6 years; 95% CI, −2.4, 1.2), weekly training units (−0.4; 95% CI, −0.9, 0.1), duration of training unit (2.9 min; 95% CI, −4.2, 10.1), weekly duration of training (−22.8 min; 95% CI, −88.6, 42.9), age (−0.6 years; 95% CI, −1.8, 0.6), height (−1.2 cm; 95% CI, −3.0, 0.6) and body mass (1.0 kg; 95% CI, −1.5, 3.5), but higher BMI (0.6 kg.m^{-2}; 95% CI, 0, 1.2) and BF (1.2%; 95% CI, 0.2, 2.2) (**Table 2**). With regards to anaerobic characteristics, no difference was observed in *P*max (−3W; 95% CI, −73, 66), *rP*max (−0.17 W.kg^{-1}; 95% CI, −1.01, 0.67), v_0 (−1.7 rpm; 95% CI, −7.6, 4.3), F_0 (0.01 kg; 95% CI, −1.55, 1.56), Ppeak (3.4 W; 95% CI, −28.8, 35.5), rPpeak (−0.09 W.kg^{-1}; 95% CI, −0.36, 0.17), Pmean (−14.7 W; 95% CI, −37.8, 8.3) and FI (2.36%; 95% CI, −0.4, 4.75), whereas EXP had lower rPmean than CON (−0.34 W.kg^{-1}; 95% CI, −0.61, −0.07).

Ppeak in EXP could be predicted from *P*max, body mass and F_0, and rPpeak from *rP*max and v_0 using the formulas presented in **Table 3**. Applying these formulas in CON, no bias was observed between actual and predicted Ppeak in W (mean difference 2.5 ± 49.8 W; 95% CI, −8.7, 13.6; $p = 0.661$) and W.kg^{-1} (mean difference 0.05 ± 0.71 W.kg^{-1}; 95% CI, −0.11, 0.21, $p = 0.525$) (**Figure 2**).

DISCUSSION

The main findings of the present study were that (a) *P*peak and *rP*peak correlated with *P*max and *rP*max, respectively, (b) the best correlates of *P*peak and *rP*peak were body mass and v_0, respectively, (c) *P*peak could be predicted from *P*max, body mass and F_0, (d) *rP*peak could be predicted from *rP*max and v_0, and (e) no bias was observed between actual and predicted Ppeak and *rP*peak.

The large correlation between *P*peak and *P*max, and rPpeak and *rP*max highlighted the possibility to use WAnT and F-v

TABLE 2 | Training, anthropometric, and anaerobic characteristics in the experimental and control group.

Variable	CON (*n* = 79)	EXP (*n* = 79)	*p*	*d*
Experience (years)	11.7 ± 4.6	11.1 ± 4.5	0.484	0.132
T.U. (number.wk^{-1})	5.0 ± 1.4	4.6 ± 1.4	0.113	0.286
Duration of T.U. (min)	89.7 ± 20.7	92.7 ± 18.5	0.418	0.153
Duration of training (min.wk^{-1})	466.3 ± 183.1	443.5 ± 177.3	0.493	0.016
Age (years)	22.9 ± 3.9	22.3 ± 3.8	0.313	0.156
Height (cm)	178.9 ± 5.7	177.7 ± 6.1	0.186	0.203
Body mass (kg)	74.3 ± 6.9	75.3 ± 8.6	0.424	0.128
BMI (kg.m^{-2})	23.2 ± 1.6	23.8 ± 2.0	0.035	0.331
BF (%)	15.2 ± 2.8	16.4 ± 3.7	0.024	0.366
Pmax (W)	1130 ± 238	1127 ± 206	0.922	0.013
rPmax (W.kg^{-1})	15.20 ± 2.80	15.03 ± 2.53	0.686	0.064
v_0 (rpm)	221.2 ± 20.2	219.5 ± 17.5	0.578	0.090
F_0 (kg)	20.73 ± 5.45	20.74 ± 4.41	0.994	0.002
Ppeak (W)	845.1 ± 102.3	848.4 ± 102.1	0.837	0.032
rPpeak (W.kg^{-1})	11.38 ± 0.90	11.29 ± 0.78	0.489	0.107
Pmean (W)	663.6 ± 78.5	648.9 ± 66.0	0.208	0.203
rPmean (W.kg^{-1})	8.95 ± 0.79	8.68 ± 0.75	0.031	0.351
FI (%)	42.12 ± 7.39	44.48 ± 7.72	0.054	0.312

Values were presented as mean ± standard deviation (SD). T.U. = training units; BMI = body mass index, BF = body fat percentage, Pmax = absolute maximal power, rPmax = relative maximal power, v_0 = theoretical maximal velocity, F_0 = theoretical maximal force, Ppeak = absolute peak power, rPpeak = relative peak power, Pmean = absolute mean power, rPmean = relative mean power, FI = fatigue index.

TABLE 3 | Summary of regression analysis in the experimental group (*n* = 79).

Dependent variable	Formula	*R*	R^2	SEE
*P*peak (W)	44.251 + 7.431 × body mass (kg) + 0.576 × *P*max (W) – 19.512 × F_0 (kg)	0.912	0.833	42.616
*r*Ppeak (W.kg^{-1})	3.148 + 0.218 × *rP*max (W.kg^{-1}) + v_0 (rpm)	0.765	0.585	0.514

R = correlation coefficient, R^2 = coefficient of determination, SEE = standard error of the estimate, Pmax = absolute maximal power, rPmax = relative maximal power, v_0 = theoretical maximal velocity, F_0 = theoretical maximal force, Ppeak = absolute peak power, rPpeak = relative peak power.

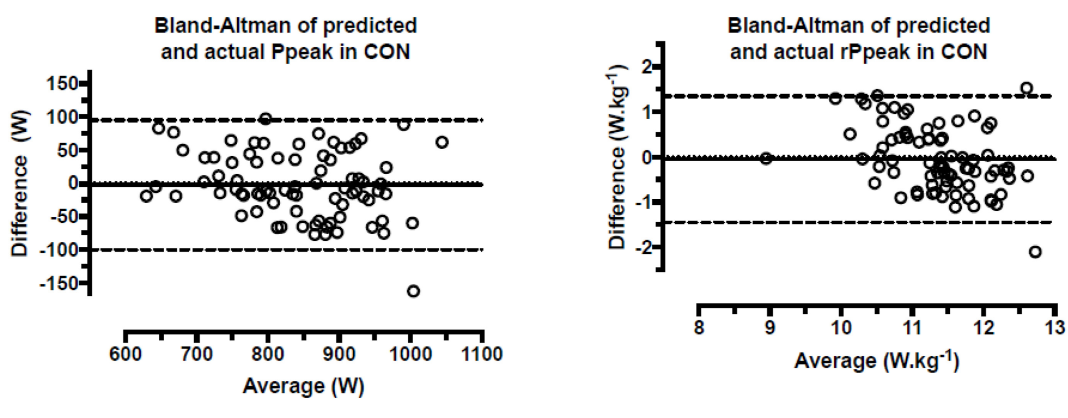


FIGURE 2 | Bland–Altman plots of predicted and actual peak power of the control group in the Wingate anaerobic test. *P*peak = absolute peak power; *rP*peak = relative peak power; CON = control group; Difference = predicted – actual; Average = (predicted + actual)/2; dashed lines represent 95% confidence intervals of bias.

test interchangeably considering the short-term duration and need for maximal effort of both tests (Driss and Vandewalle, 2013). In addition, the larger values of *P*max and *rP*max than *P*peak and *rP*peak were in agreement with previous studies using both the tests (Jemni et al., 2006; Souissi et al., 2008; Ingle and Tolfrey, 2013). An explanation of this difference might be that the highest power output in the F-v test was estimated, whereas it was measured in the WAnT at a given braking force (which was set considering each participant's body mass).

Comparing the predictors of *P*peak and *rP*peak, it was observed that different anthropometric and F-v characteristics played a predicting role in each case. The best predictor of *P*peak was body mass highlighting the relationship of muscle power with human size (Bahenský et al., 2020; Taketomi et al., 2021). Previously, it was shown that *rP*peak was related with 5 m, 30 m sprint times, maximal voluntary isometric contraction of the knee extensors, half squat repetition maximal and countermovement jump height in soccer players (Boraczyński et al., 2020), performance of short and maximal effort that might be evaluated by the F-v test. Comparing the prediction models of *P*peak and *rP*eak, it was observed that the coefficient of determination was higher for the absolute than for the relatively score of peak power. Peak power related very largely with body mass, and consequently, since body mass was partitioned out in *rP*peak, a weaker model was shown for the relative score of peak power.

A limitation of this study was that the findings referred to specific performances in the selected anaerobic tests. Since the bias was larger in low and high anaerobic performances, caution would be needed to generalize the developed prediction equations to other populations. However, there was large interindividual variability in the agreement between the actual and the predicted scores; thus, the use of the developed equations to predict *P*peak and *rP*peak should be avoided when precision at an individual level would be needed in soccer players with small interindividual variation. On the other hand, the developed equations provided a practical tool to coaches and trainers to predict the average *P*peak and *rP*peak of a group of athletes from their F-v test. Accordingly, the F-v test might be considered as a diagnostic tool of team instead of individual WAnT performance. Future studies should examine the interchangeability of these tests in soccer players differing for sex, age, and performance level.

CONCLUSION

The findings of this work provided indirect estimates of the average *P*peak and *rP*peak of the WAnT for a group of players that would be useful especially in periods when this test should not be applied considering the fatigue it causes. In this context, the F-v test can be considered as an alternative of exercise testing for the average *P*peak and *rP*peak of a group of soccer players rather than for predicting individual scores when the interindividual variation of performance is small.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board of EPL. The study was conducted according to the guidelines of the Declaration of Helsinki. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

PN collected all data, performed the analyses, and drafted the manuscript. BK helped in drafting the manuscript. Both authors contributed to the article and approved the submitted version.

REFERENCES

Almansba, R., Boucher, V. G., Parent, A. A., and Comtois, A. S. (2019). Repeated linear and quadrangular sprint as a function of anaerobic power. *J. Strength Cond. Res.* 33, 2177–2184. doi: 10.1519/jsc.0000000000002358

Aloui, G., Hermassi, S., Hammami, M., Cherni, Y., Gaamouri, N., Shephard, R. J., et al. (2020). Effects of elastic band based plyometric exercise on explosive muscular performance and change of direction abilities of male team handball players. *Front. Physiol.* 11:604983. doi: 10.3389/fphys.2020.604983

Bahenský, P., Marko, D., Bunc, V., and Tlustý, P. (2020). Power, muscle, and take-off asymmetry in young soccer players. *Int. J. Environ. Res. Public Health* 17:6040. doi: 10.3390/ijerph17176040

Ben Ayed, K., Latiri, I., Dore, E., and Tabka, Z. (2011). Leg muscle power in 12-year-old black and white Tunisian football players. *Res. Sports Med.* 19, 103–117. doi: 10.1080/15438627.2011.556527

Blonc, S., Casas, H., Duché, P., Beaune, B., and Bedu, M. (1998). Effect of recovery duration on the force-velocity relationship. *Int. J. Sports Med.* 19, 272–276. doi: 10.1055/s-2007-971917

Boraczyński, M., Boraczyński, T., Podstawski, R., Wójcik, Z., and Gronek, P. (2020). Relationships between measures of functional and isometric lower body strength, aerobic capacity, anaerobic power, sprint and countermovement jump performance in professional soccer players. *J. Hum. Kinet.* 75, 161–175. doi: 10.2478/hukin-2020-0045

Bouhlel, E., Chelly, M. S., Gmada, N., Tabka, Z., and Shephard, R. (2010). Effect of a prior force-velocity test performed with legs on subsequent peak power output measured with arms or vice versa. *J. Strength Cond. Res.* 24, 992–998. doi: 10.1519/JSC.0b013e3181cb2499

Chtourou, H., Trabelsi, K., Boukhris, O., Ammar, A., Shephard, R. J., and Bragazzi, N. L. (2019). Effects of Ramadan fasting on physical performances in soccer players: a systematic review. *Tunis. Med* 97, 1114–1131.

Dotan, R., and Bar-Or, O. (1980). Climatic heat stress and performance in the Wingate Anaerobic Test. *Eur. J. Appl. Physiol. Occup. Physiol.* 44, 237–243. doi: 10.1007/bf00421623

Driss, T., and Vandewalle, H. (2013). The measurement of maximal (anaerobic) power output on a cycle ergometer: a critical review. *Biomed. Res. Int.* 2013:589361. doi: 10.1155/2013/589361

Eston, R., and Reilly, T. (2009). *Kinanthropometry and Exercise Physiology Laboratory Manual. Tests, Procedures and Data: Volume 1: Anthropometry*, 3 Edn. London: Routledge.

Freitas, T. T., Pereira, L. A., Reis, V. P., Fernandes, V., Alcaraz, P. E., Azevedo, P., et al. (2021). Effects of a congested fixture period on speed and power performance of elite young soccer players. *Int. J. Sports Physiol. Perform.* Online ahead of print, doi: 10.1123/ijspp.2020-0280

Hammami, M., Gaamouri, N., Shephard, R. J., and Chelly, M. S. (2019). Effects of contrast strength vs. plyometric training on lower-limb explosive performance, ability to change direction and neuromuscular adaptation in soccer players. *J. Strength Cond. Res.* 33, 2094–2103. doi: 10.1519/jsc.0000000000002425

Ingle, L., and Tolfrey, K. (2013). The variability of high intensity exercise tests in -pre-pubertal boys. *Int. J. Sports Med.* 34, 1063–1069. doi: 10.1055/s-0032-1327714

Jaafar, H. (2017). Allometric scaling of power-force-velocity ergometry profiles in men. *Ann. Hum. Biol.* 44, 648–651. doi: 10.1080/03014460.2017.1355012

Jemni, M., Sands, W. A., Friemel, F., Stone, M. H., and Cooke, C. B. (2006). Any effect of gymnastics training on upper-body and lower-body aerobic and power components in national and international male gymnasts? *J. Strength Cond. Res.* 20, 899–907. doi: 10.1519/r-18525.1

Joo, C. H., and Seo, D. I. (2016). Analysis of physical fitness and technical skills of youth soccer players according to playing position. *J. Exerc. Rehabil.* 12, 548–552. doi: 10.12965/jer.1632730.365

Keir, D. A., Thériault, F., and Serresse, O. (2013). Evaluation of the running-based anaerobic sprint test as a measure of repeated sprint ability in collegiate-level soccer players. *J. Strength Cond. Res.* 27, 1671–1678. doi: 10.1519/JSC.0b013e31827367ba

Lepschy, H., Woll, A., and Wäsche, H. (2021). Success factors in the FIFA 2018 World Cup in Russia and FIFA 2014 World Cup in Brazil. *Front. Psychol.* 12:638690. doi: 10.3389/fpsyg.2021.638690

Longo, U. G., Sofi, F., Candela, V., Risi Ambrogioni, L., Pagliai, G., Massaroni, C., et al. (2021). The influence of athletic performance on the highest positions of the final ranking during 2017/2018 Serie A season. *BMC Sports Sci. Med. Rehabil.* 13:32. doi: 10.1186/s13102-021-00259-3

Miller, J. M. (2020). Acute effects of static stretching on Wingate testing in men. *J. Sports Med. Phys. Fitness* 60, 974–978. doi: 10.23736/s0022-4707.20.10349-9

Nikolaidis, P. T., Ruano, M. A., de Oliveira, N. C., Portes, L. A., Freiwald, J., Leprêtre, P. M., et al. (2016). Who runs the fastest? Anthropometric and physiological correlates of 20 m sprint performance in male soccer players. *Res. Sports Med.* 24, 341–351. doi: 10.1080/15438627.2016.1222281

Sanchez, A. M., Collomp, K., Carra, J., Borrani, F., Coste, O., Préfaut, C., et al. (2012). Effect of acute and short-term oral salbutamol treatments on maximal power output in non-asthmatic athletes. *Eur. J. Appl. Physiol.* 112, 3251–3258. doi: 10.1007/s00421-011-2307-3

Souissi, N., Souissi, M., Souissi, H., Chamari, K., Tabka, Z., Dogui, M., et al. (2008). Effect of time of day and partial sleep deprivation on short-term, high-power output. *Chronobiol. Int.* 25, 1062–1076. doi: 10.1080/07420520802551568

Taketomi, S., Kawaguchi, K., Mizutani, Y., Yamagami, R., Sameshima, S., Takei, S., et al. (2021). Anthropometric and musculoskeletal gender differences in young soccer players. *J. Sports Med. Phys. Fitness* 61, 1212–1218. doi: 10.23736/s0022-4707.21.11617-2

Thom, G., Kavaliauskas, M., and Babraj, J. (2020). Changes in lactate kinetics underpin soccer performance adaptations to cycling-based sprint interval training. *Eur. J. Sport Sci.* 20, 486–494. doi: 10.1080/17461391.2019.1635650

Vandewalle, H., Pérès, G., Heller, J., and Monod, H. (1985). All out anaerobic capacity tests on cycle ergometers. A comparative study on men and women. *Eur. J. Appl. Physiol. Occup. Physiol.* 54, 222–229. doi: 10.1007/bf02335934

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Psychology

SYSTEMATIC REVIEW
published: 02 December 2021
doi: 10.3389/fpsyg.2021.772201

Perceptual-Motor and Perceptual-Cognitive Skill Acquisition in Soccer: A Systematic Review on the Influence of Practice Design and Coaching Behavior

Fynn Bergmann[1*†], **Rob Gray**[2], **Svenja Wachsmuth**[1†] **and Oliver Höner**[1†]

[1] Institute of Sports Science, Eberhard Karls University Tübingen, Tübingen, Germany, [2] Human Systems Engineering, Arizona State University, Mesa, AZ, United States

Facilitating players' skill acquisition is a major challenge within sport coaches' work which should be supported by evidence-based recommendations outlining the most effective practice and coaching methods. This systematic review aimed at accumulating empirical knowledge on the influence of practice design and coaching behavior on perceptual-motor and perceptual-cognitive skill acquisition in soccer. A systematic search was carried out according to the PRISMA guidelines across the databases SPORTDiscus, PsycInfo, MEDLINE, and Web of Science to identify soccer-specific intervention studies conducted in applied experimental settings (search date: 22[nd] November 2020). The systematic search yielded 8,295 distinct hits which underwent an independent screening process. Finally, 34 eligible articles, comprising of 35 individual studies, were identified and reviewed regarding their theoretical frameworks, methodological approaches and quality, as well as the interventions' effectiveness. These studies were classified into the following two groups: Eighteen studies investigated the theory-driven instructional approaches Differential Learning, Teaching Games for Understanding, and Non-linear Pedagogy. Another seventeen studies, most of them not grounded within a theoretical framework, examined specific aspects of practice task design or coaches' instructions. The Downs and Black checklist and the Template for Intervention Description and Replication were applied to assess the quality in reporting, risk of bias, and the quality of interventions' description. Based on these assessments, the included research was of moderate quality, however, with large differences across individual studies. The quantitative synthesis of results revealed empirical support for the effectiveness of coaching methodologies aiming at encouraging players' self-exploration within representative scenarios to promote technical and tactical skills. Nevertheless, "traditional" repetition-based approaches also achieved improvements with respect to players' technical outcomes, yet, their impact on match-play performance remains widely unexplored. In the light of the large methodological heterogeneity of the included studies (e.g., outcomes or control groups' practice activities), the presented results

Edited by:
José Afonso, Faculty of Sports, University of Porto, Portugal

Reviewed by:
Felippe Cardoso, Juiz de Fora Federal University, Brazil
Gustavo De Conti Teixeira Costa, Universidade Federal de Goiás, Brazil
Henrique de Oliveira Castro, Federal University of Mato Grosso, Brazil

***Correspondence:**
Fynn Bergmann
fynn.bergmann@uni-tuebingen.de

†ORCID:
Fynn Bergmann
orcid.org/0000-0001-8323-3157
Svenja Wachsmuth
orcid.org/0000-0003-1964-6875
Oliver Höner
orcid.org/0000-0002-3108-1531

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: 07 September 2021
Accepted: 31 October 2021
Published: 02 December 2021

Citation:
Bergmann F, Gray R, Wachsmuth S and Höner O (2021) Perceptual-Motor and Perceptual-Cognitive Skill Acquisition in Soccer: A Systematic Review on the Influence of Practice Design and Coaching Behavior. Front. Psychol. 12:772201. doi: 10.3389/fpsyg.2021.772201

need to be interpreted by taking the respective intervention characteristics into account. Overall, the current evidence needs to be extended by theory-driven, high-quality studies within controlled experimental designs to allow more consolidated and evidence-based recommendations for coaches' work.

Keywords: football (soccer), talent development, ecological dynamics, dynamical systems, information-processing

INTRODUCTION

Sport coaches face multiple challenges, one of which is to facilitate athletes' skill acquisition to improve performance (Gould and Mallett, 2021). Due to the dynamic and interactive character of team sports games, a plethora of skills is required to act successfully during gameplay. In soccer, these skills specifically encompass perceptual-motor (e.g., technical) and perceptual-cognitive (e.g., tactical) components (Williams et al., 2020). Knowledge about these and further relevant performance factors is not only important to identify talented players, it is also essential for developing these performance factors systematically through effective practice and coaching. While recent systematic reviews document the growing body of knowledge about soccer-specific performance characteristics and talent predictors, less is known on how to promote these factors effectively, reinforcing the call for intervention research (Williams et al., 2020; O'Connor et al., 2021).

Most intervention research on the development of performance factors in soccer is concerned with the players' physical fitness and physiological capabilities (for overviews see Bujalance-Moreno et al., 2018; Zouhal et al., 2020). Considerably fewer studies investigated the promotion of soccer-specific skills based on psychological and motor learning theories (Williams and Hodges, 2005). This smaller scope of scientific work is primarily attributed to methodological challenges in assessing behavioral changes in players, especially in highly dynamic and unpredictable match-play situations. For this reason, laboratory-based research on the acquisition of closed soccer skills has made the primary contribution to our general understanding of skill acquisition (e.g., Anderson and Sidaway, 1994; Hodges et al., 2005). Often conducted with novice participants, those studies seem to not only lack transferability to a pitch-based coaching context but also to superior skill-level players (Wulf and Shea, 2002; Farrow and Robertson, 2017). As a possible consequence, there is an emerging trend toward intervention studies anchored in more representative settings and with more experienced players (e.g., Práxedes et al., 2016; Roberts et al., 2020).

Theoretical Perspectives on Skill Acquisition

Besides methodological difficulties in designing intervention research, also the theoretical underpinnings of skill acquisition pose challenges for developing effective practice. There are different perspectives on the organization and development of skills, possibly leading to contradictory implications for coaches' work. Historically, substantial advances have been made with regards to understanding the processes linked to skill acquisition, but it remains a dynamic and disputed topic among researchers (Whitall et al., 2020a,b).

In current research, two influential theoretical perspectives can be distinguished that emerged from cognitive psychology, on the one hand, and ecological psychology/dynamical systems theory, on the other hand (Anson et al., 2005).[1] According to an understanding grounded in *cognitive "information-processing"* theories, there is an ideal way to perform a skill that is to be learned through a stage-linear process (Fitts and Posner, 1979). Based on the schema theory of motor learning (Schmidt, 1975), a skill consists of invariants that are stored through mental representations in so-called generalized motor programs (GMPs). For utilizing GMPs in dynamic game-related situations, players must learn to parameterize the skill, that means, learn how to adjust the skill to the requirements of any respective situation. Within this theoretical perspective, performing a game action relates to a subsequent three-stage process from stimulus identification (i.e., perception), response selection (i.e., decision), and response programming (i.e., action; Schmidt et al., 2019).

A different, opposing view to this often called "traditional" standpoint emerges from an *ecological/dynamical systems* perspective where skill acquisition is considered a process of exploration and self-organization. Based on Newell's (1986) constraints-based model, individuals interact with the environment and the tasks of the given situation by exploring individual movement solutions in a non-linear fashion. In this approach, there is no one ideal, "correct" technique for performing a skill. Rather, there is substantial variability both across and within individuals (i.e., "repetition without repetition"; Bernstein, 1967). According to this viewpoint, performing game actions depends on the direct perception of affordances from the environment, implying that perception, and action are considered inherently coupled (Gibson, 1979).

Practice and Coaching Methods to Promote Skill Acquisition in Soccer

In searching for the most supportive methods to improve players' skills, it is worthwhile to look at the early stages of playing soccer during childhood: In these stages, the process of skill acquisition can occur in an implicit and unstructured way within informal and child-led settings, such as street soccer (Uehara et al., 2018). There is evidence that a high amount of such self-organized soccer gameplays, as well as multi-sport practice in childhood, is positively associated with achieving excellence in adult soccer (Forsman et al., 2016; Güllich et al., 2021). However, when

[1]For further explanations see for example: https://www.youtube.com/watch?v=cCsezh7ijzs.

looking at the pathways of elite players, it is indisputable that formal soccer-specific and coach-led practice is indispensable to improve and sustain players' skill level, too (Sieghartsleitner et al., 2018; Hendry and Hodges, 2019). In this goal-directed process, coaches are challenged by a variety of methodological decisions relating to the skill itself but also contextual factors, such as the athlete's performance level, age, or available time to achieve an outcome (Côté and Gilbert, 2009). Therefore, coaches likely need a "blended tool kit" (Price et al., 2019, p. 126), equipped with practice and coaching methods in order to find effective context-specific solutions to facilitate player learning and performance.

To describe these "tools", the terms *training form* (i.e., decontextualized repetitive drills) and *playing form* (i.e., game-related, representative situations) are commonly used to classify practice activities in soccer (Ford et al., 2010; O'Connor et al., 2018). Yet, these terms only provide a broad picture of the accompanying task demands so that more sophisticated differentiation is needed. One of that is the degree of variability within (i.e., trial-to-trial) and between (i.e., contextual interference) practiced skills that can be scaled in drills and game-based tasks (Stratton et al., 2004; Magill and Anderson, 2020). Further, the specificity describes whether practice conditions reflect competitive demands in terms of motor- and sensory-related parameters (Proteau, 1992; Farrow and Robertson, 2017). Besides practice activities, there is also a wide array of coaching behaviors, such as demonstrations, instructions, and feedback which are used to accentuate the practice demands (Hendry et al., 2015; Otte et al., 2020). For instance, instructive behaviors may differ depending on whether explicit or implicit learning processes should be promoted in the players.

Insights to which extent coaches make use of the outlined tools during pitch-based work are given by systematic observations in "real-world" coaching contexts (Cushion et al., 2012a; Partington and Cushion, 2013; Partington et al., 2014). Many of these studies have displayed the "challenging tradition" of practice, instruction, and skill acquisition in terms of the predominant use of unrepresentative drill-based activities and a high amount of prescriptive instructions by the coaches (Williams and Hodges, 2005). More recent studies show a trend regarding more game-realistic activities which are more closely aligned to competitive demands (O'Connor et al., 2018; Roca and Ford, 2020). Nonetheless, there still seems to be potential toward greater consideration of skill acquisition research within soccer coaches' work (O'Connor et al., 2017; Farrow, 2021).

In contrast to the outlined traditional approach, characterized by the predominant use of decontextualized drill-based activities and directive instructions, instructional approaches providing alternative strategies have gained increasing popularity in soccer. Grounded in an educative and constructivist perspective, *Teaching Games for Understanding* (TGFU; Bunker and Thorpe, 1982) is a game-centered approach that aims to improve tactical intelligence through simplified, game-related situations. The accompanying guided discovery approach to coaching is intended to explicitly enhance players in solving tactical problems. As another approach, *Non-linear Pedagogy* (NLP; Chow et al., 2011) provides key principles to practice and coaching and is shaped by an ecological dynamics viewpoint. According to NLP, functional variability of skills can be achieved through perception-action couplings during practice, by applying representative learning designs, and a "hands-off" facilitative approach to coaching. NLP aims to support players in finding individual movement solutions through a non-linear process of learning. Lastly, based on dynamical systems theory, *Differential Learning* (DL; Schöllhorn, 1999) assumes that athletes need to adapt to constant perturbations in dynamic competitive environments. Thus, practicing skills with additional random fluctuations ("noise") offers the opportunity to explore and self-organize individual functional movement patterns.

Considering the wide array of possible practice and coaching approaches, Williams et al. (2020) and O'Connor et al. (2021) call for intervention research on soccer players' skill acquisition to get a deeper insight into the effectiveness of different methods. Recent systematic reviews and meta-analyses within these and related fields pooled intervention research from educational settings (Abad Robles et al., 2020), focused on the effectiveness of one instructional approach (e.g., DL; Tassignon et al., 2021), or merely examined one specific outcome (e.g., decision-making; Silva et al., 2020). While these reviews included studies from various sports and often different experimental settings, there is no systematic review accumulating evidence on the effectiveness of practice and coaching methods grounded in different theoretical perspectives to skill acquisition from a soccer-specific viewpoint.

The Present Study

This systematic review aims to pool empirical knowledge from intervention research on the effectiveness of different practice and coaching methods on skill acquisition in soccer. In contrast to previous systematic reviews and meta-analyses, the current review is explicitly set out to focus on the following attributes: First, it focuses on intervention research conducted in applied ("pitch-based") experimental settings which included experienced soccer players as participants rather than novices. Such studies provide the ecological validity necessary to offer the most pertinent support for soccer coaches' actual work. Next, it was deemed vital to investigate studies grounded in different theoretical skill acquisition approaches to explore how different assumptions impact an interventions' design as well as to discuss the effectiveness of different approaches regarding the acquisition and learning of soccer-specific skills. Finally, considering both perceptual-motor and perceptual-cognitive skills as outcomes was perceived mandatory due to their interrelationship during matchplay. As there is no overview of intervention research in soccer considering these aspects, knowledge on the methodological characteristics and rigor is required to estimate the current potential for drawing evidence-based recommendations for coaches' work.

To this end, soccer-specific intervention studies conducted in applied experimental settings with soccer players were reviewed to answer the following research questions considering three overarching perspectives:

I. *Theoretical perspective:* What were the interventions' underlying frameworks to skill acquisition? How did these impact the practice design and coaches' behavior?
II. M*ethodological perspective:* What study designs, participant samples, instruments, and statistical methods were applied? What was the quality in reporting and risk of bias within studies?
III. *Outcome-related perspective:* To what degree did the interventions contribute to effective perceptual-motor and perceptual-cognitive skill acquisition in the players?

METHODS

A systematic review was conducted according to the guidelines of preferred reporting items for systematic review and meta-analyses (PRISMA; Moher et al., 2009). On November 4th 2020, a PRISMA-Protocol (PRISMA-P; Moher et al., 2015) was pre-registered in the Open Science Framework, outlining the objectives of this systematic review, the systematic search strategy, methods for assessing the methodological quality of individual studies, as well as predetermined methods for data extraction and synthesis in detail (Bergmann et al., 2020).

Systematic Search and Eligibility Criteria

On November 22nd 2020, a systematic search was conducted across the databases SPORTDiscus, PsycInfo, MEDLINE (via EBSCOHost, respectively), and Web of Science (considering the categories Sports Science and Psychology). Each database was searched for peer-reviewed academic articles in English language without limitations for publication year. The systematic search strategy was developed by the research group in consultation with two librarians who helped to optimize search terms and to identify the most appropriate databases to best address the objectives of this systematic review (Harari et al., 2020). The following terms and operators were searched in each database considering titles and keywords (further details of the systematic database search and the respective settings of each database are documented within **Supplementary Material I**):

(football* OR soccer)
AND
(intervention OR train* OR program* OR approach OR pract* OR effect* OR impact OR improv* OR learn* OR perform* OR coach* OR "skill acquisition" OR cognit* OR ecologic* OR constraints OR "information processing")
NOT
(novice OR referee OR injur* OR pupil* OR class OR goalkeep* OR NFL OR "american football" OR "australian football")

The inclusion criteria for study selection are presented in **Table 1** according to the PICOS components. In accordance with Spittle's (2021) classification of intervention research, only studies in at least applied settings were included. Additionally, studies were excluded if they examined novices, goalkeepers, referees, or athletes with mental or physical disabilities. Besides that, interventions focusing on injury prevention or rehabilitation (including warm-up programs), as well as interventions that only included physical or physiological training exercises without a ball (i.e., fitness training), were not considered. This was also true for such studies which only assessed physical or physiological outcomes. Due to the lower ecological validity, laboratory research designs, but also imagery or virtual-reality interventions, were excluded.

TABLE 1 | Specification of inclusion criteria regarding the components participants, interventions, comparators, outcomes, and study designs (PICOS).

Component	Inclusion criteria
P	• Healthy and injury-free soccer players (i.e., with previous soccer experience) of all age groups and sexes.
I	• Soccer-specific interventions conducted in applied (i.e., pitch-based) settings (cf. Spittle, 2021, p. 10).
C	• Studies without CG were included for review but only analyzed regarding theoretical frameworks as well as methodological characteristics and quality (i.e., perspectives I and II). In terms of the interventions' effectiveness (i.e., perspective III), only controlled designs including non-active and/or active control groups were considered.
O	• Soccer-specific perceptual-motor and/or perceptual-cognitive skills.
S	• Any type of quantitative (i.e., quasi-experimental and experimental) intervention study investigating the effectiveness of practice and coaching methods with regard to the acquisition or learning of the aforementioned soccer-specific skills.

CG, control group.

Article Screening

The search results were exported to and managed with EndNote (Version X9.3). EndNote was also used to remove duplicates automatically. Additionally, the first author and a trained research assistant screened all titles independently to remove previously missed duplicates manually. Throughout an independent screening process following the PRISMA guidelines, potentially eligible articles were checked against the inclusion and exclusion criteria by both reviewers. The inter-rater agreement (IRA) was calculated using the percentage of agreement as well as Cohen's Kappa (κ; Hallgren, 2012).

The PRISMA flowchart in **Figure 1** displays the systematic search results. The initial database search yielded 13,318 hits. Three articles were additionally added through other sources (Hossner et al., 2016; Bozkurt, 2018; Ozuak and Çaglayan, 2019). After removing 5,026 duplicates, 8,295 titles were screened independently by the first author and a trained research assistant. The previously initiated reviewer training comprised an independent title screening of ∼10% of identified records and a subsequent discussion of all differently categorized articles based on the inclusion and exclusion criteria. After screening all titles independently, the IRA yielded a sufficient agreement between the two reviewers (97.58%; $\kappa = 0.56$). If at least one reviewer argued for inclusion at this stage, the article was moved into the next stage of abstract screening. At this point, 338 potentially

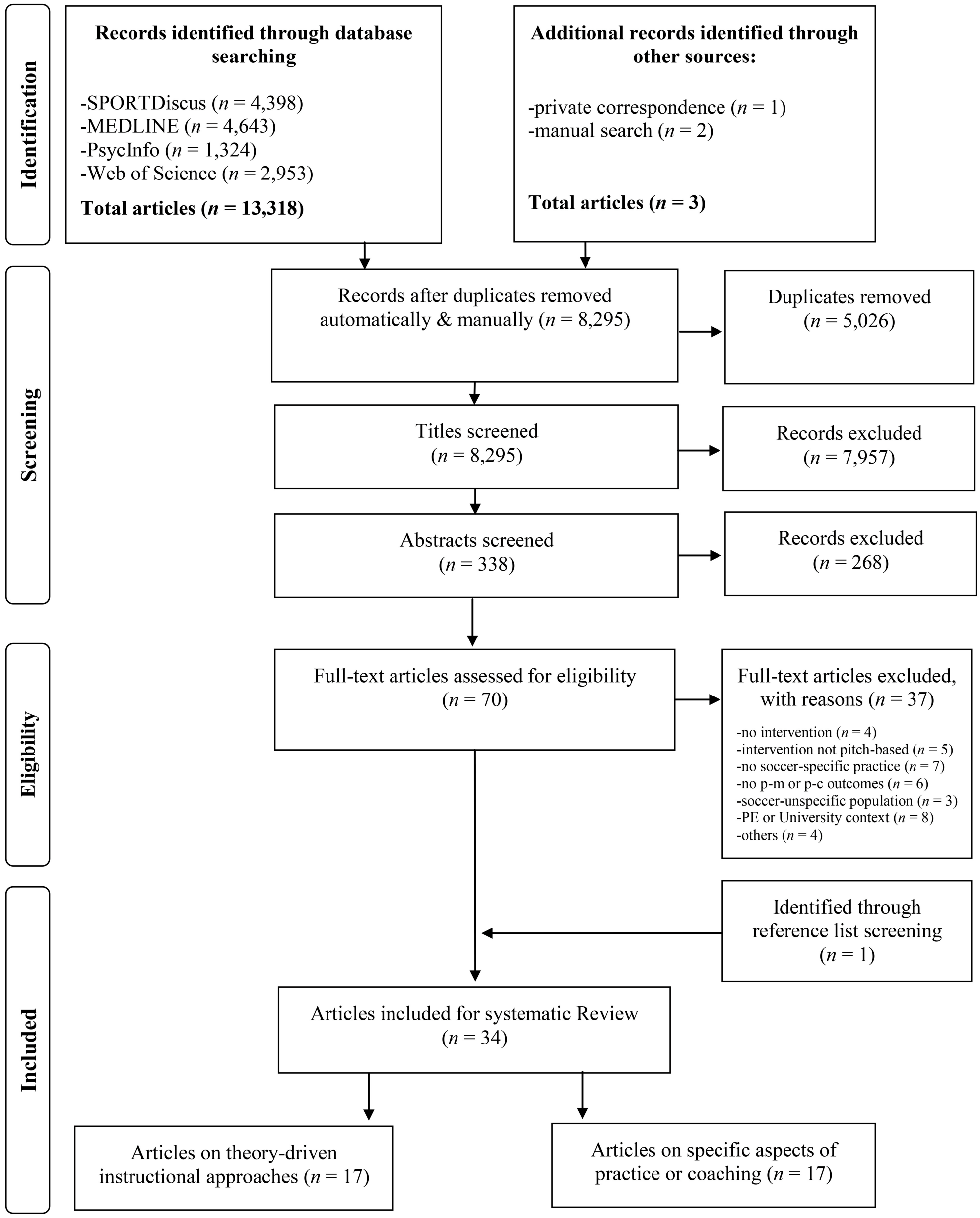


FIGURE 1 | PRISMA flowchart for the documentation of the systematic search process. Notes: The 17 articles on theory-driven instructional approaches include 18 individual studies. PE, Physical Education; p-c, perceptual-cognitive; p-m, perceptual-motor.

relevant abstracts were examined and an excellent IRA was reached (94.67%; $\kappa = 0.92$). In case of initial disagreement, study records were discussed by the two reviewers and a decision for or against full-text screening was made. Lastly, 70 full texts were screened independently, the IRA was again found to be excellent (91.43%; $\kappa = 0.87$). Uncertainties were discussed with the whole project group. Within this process, 33 articles were identified and one more article was found through manual reference list screening (Schöllhorn et al., 2012). Finally, 34 articles were included for systematic review.

Data Extraction

The data of included studies were extracted using a Microsoft Excel spreadsheet. All accessible information about the study, participant characteristics, intervention characteristics, instruments, outcome variables, as well as statistical techniques used to assess outcome effects were extracted. To determine whether a quantitative synthesis is possible based on reported data, descriptive and inferential statistics were also extracted. Necessary missing data was requested from the corresponding authors.

Assessment of Quality in Reporting and Risk of Bias

To judge the quality in reporting and the risk of bias in individual studies, all studies underwent a detailed assessment using an augmented version of the *Downs and Black Checklist* (Downs and Black, 1998) as well as a slightly modified version of the *Template for Intervention Description and Replication* (TIDieR; Hoffmann et al., 2014).[2]

The Downs and Black Checklist (Downs and Black, 1998) was developed for the rating of both randomized and non-randomized studies and has been recently used within systematic reviews and meta-analyses in sports sciences (Davies et al., 2017; Grgic et al., 2018; Ramos et al., 2020). Conventions for the studies' quality scores used in previous reviews were adopted but transferred to percentage as not all items were applicable to all studies. Good methodological quality is represented by a score $\geq$ 70%. A score $\leq$ 35% represents a low methodological quality. Scores between these thresholds were considered as moderate.

The TIDieR (Hoffmann et al., 2014) consists of 12 items to assess the quality in reporting of interventions. With the objectives of this systematic review in mind, a detailed intervention description is essential to interpret the results, allow potential replications, and provide coaches with evidence-based recommendations for their work.

To provide a reliable assessment, a similar procedure as for the systematic screening process was applied. An excellent IRA for both the Downs and Black checklist (95.76% [90.9, 100%]; κ = 0.91 [0.71, 1%]) and the TIDieR (96.43% [81.1, 100%]; κ = 0.92 [0.71, 1%]) was achieved. Results for both scales were reported by mean (*M*), standard deviation (*SD*), median (*Mdn*), and range.

Narrative and Quantitative Synthesis

The study characteristics and results were synthesized narratively for all included studies to provide a descriptive overview of the existent research. Based on this narrative synthesis as well as the judgement of quality in reporting and risk of bias, it was discussed whether an additional quantitative synthesis is possible according to criteria outlined in the PRISMA-P (Bergmann et al., 2020).

Performing a meta-analysis was deemed inappropriate due to the heterogeneity of dependent variables and study designs (e.g., randomized/non-randomized studies; parallel-group/cross-over designs), as well as differences in the studies' quality. More specifically, pooling the effects as done within a meta-analysis was thought to lead to a comparison of dissimilar studies, the inclusion of poorly designed research, and thus, to invalidate results (Tod, 2019; Deeks et al., 2021). However, to estimate the intervention effect sizes in controlled studies, the effect size *d* was calculated in two different ways based on the reported data in the original publications. *First,* if the effectiveness was analyzed by group × time interactions, *d* was calculated from the interaction effect according to Cohen (1988). *Second*, if differences between groups at pre- and post-test were used to analyze the effectiveness (i.e., acquisition effects), d_{ppc2} was computed (see Equations 1–3; Morris, 2008; p. 369):

$$d_{ppc2} = c_P \left[\frac{\left(M_{post,\,T} - M_{pre,\,T}\right) - \left(M_{post,C} - M_{pre,C}\right)}{SD_{pre}} \right] \quad (1)$$

where the pooled standard deviation is defined as

$$SD_{pre} = \sqrt{\frac{(n_T - 1)\, SD^2_{pre,T} + (n_C - 1) SD^2_{pre,C}}{n_T + n_C - 2}} \quad (2)$$

and

$$c_P = 1 - \frac{3}{4\,(n_T + n_C - 2) - 1} \quad (3)$$

The d_{ppc2} was also applied when multivariate statistics were used to classify effects for single outcome variables. If a retention-test was conducted and all relevant data was available, d_{ppc2} was calculated using pre- and retention-test data to estimate learning effects.

To consider the intervention duration as a potential moderator, studies were classified as short- (i.e., $\leq$ 6 sessions or 180 min), mid- (i.e., $\leq$ 24 sessions or 720 min), and long-term (i.e., $\geq$ 25 sessions or 2,250 min) interventions. Similar approaches to synthesize intervention effects quantitatively were recently used within systematic reviews in sports science research (e.g., Demetriou and Höner, 2012; Raabe et al., 2019). Results are reported by the range of significant and non-significant effects, the percentage of significant effects, as well as the median when three or more effect sizes were found. Recommendations by Cohen (1988) were used to classify small ($d \geq 0.20$), medium ($d \geq 0.50$), and large effects ($d \geq 0.80$). Effects displayed as positive values represent improvements in the respective outcome in favor of the intervention groups (IGs), while negative values represent greater improvements in control groups (CGs).

RESULTS

From the 34 identified articles, 85.7% were published between 2010 and 2020, revealing an increase in the number of relevant publications in recent years. The publication by Schöllhorn et al. (2006) includes two studies so that in total 35 individual studies were reviewed. All 35 studies were analyzed regarding their theoretical frameworks and methodological approaches (objectives 1 and 2). To investigate and compare the effectiveness (objective 3), only the 27 controlled studies were considered, while 8 studies without a CG were excluded.

Theoretical Frameworks and Intervention Content (Perspective 1)

The studies can be grouped into two overarching categories (see **Figure 1**). The *first group* (n = 18) represents studies in which interventions were designed based on theory-driven instructional approaches to practice and coaching. The *second group* (n = 17) includes studies investigating specific aspects of

[2]The modified checklists, including further specifications of the items, are accessible in the OSF project for this publication (https://osf.io/85tjg/).

TABLE 2 | Characteristics of studies investigating theory-driven instructional approaches to practice and coaching ($n = 18$).

Study	Country (ISO code)	Study design	Participants				Study description
			N (groups)	Age (years)	Sex	PL	
Differential Learning (DL; *n* = 9)							
Bozkurt (2018)	TUR	Pre- to post-test design with CG	15 (2)	Age = 15	n. r.	n. r.	A supplemental drill-based DL program to improve passing, dribbling, and feet-juggling was compared to a drill-based TL program with corrective feedback.
Coutinho et al. (2018)	POR	Pre- to post-test design with CG	30 (4)	$M_{DLU15} = 14.2 \pm 0.8$ $M_{DLU17} = 15.8 \pm 0.8$ $M_{CGU15} = 13.9 \pm 0.5$ $M_{CGU17} = 16.1 \pm 0.7$	male	RL	An enrichment DL program to improve attackers' technical skills and creativity was compared to a non-active CG. DL included physical literacy, technical exercises, and SSGs.
Gaspar et al. (2019)	POR	Pre- to post-test design	20 (1)	$M = 13.8 \pm 0.6$	n. r.	RL	Acute effects of a session blocked DL in comparison to a session blocked TL with movement feedback. Both sessions aimed at improving goal-shooting velocity and accuracy.
Hossner et al. (2016)	GER	Pre- to post-test design with CG	28 (3)	$M = 13.8 \pm 1.1$ Range: 12–15	male	RL	Comparison of drill-based DL without augmented feedback, DL with augmented feedback, and methodologically structured TL to promote players' shooting accuracy.
Ozuak and Çaglayan (2019)	TUR	Pre- to post-test design with CG	52 (2)	$M_{IG} = 12.03 \pm 0.44$ $M_{CG} = 12.05 \pm 0.46$ Range: 12–13	n. r.	AL	Drill-based DL, implemented in the regular practice schedule, was compared to a CG that participated in the regular TL practice.
Santos et al. (2018)	POR	Pre- to post-test design with CG	40 (4)	$M_{DLU13} = 11.1 \pm 0.5$ $M_{DLU15} = 13.1 \pm 0.3$ $M_{CGU13} = 11.4 \pm 0.5$ $M_{CGU15} = 13.0 \pm 0.8$	n. r.	RL	Game-based DL, focusing on intertrial variability, was compared to game-based practice supported by specific instructions and error correction of a coach. The practice programs are aimed at improving the players' creativity.
Schöllhorn et al. (2006; study 1)	GER	Pre- to post-test design with CG	8 (2)	Adult	n. r.	5^{th} Div.	Drill-based DL to improve passing accuracy was compared to TL based on little inter-trial variability and descriptions of the ideal movement technique.
Schöllhorn et al. (2006; study 2)	GER	Pre-, to post-, and ret-test design with CG	18 (2)	Adult	male	5^{th} & 7^{th} Div.	Blocked DL to improve goal shooting accuracy was compared to TL based on a high number of repetitions and corrective feedback.
Schöllhorn et al. (2012)	GER	Pre-, to post-, and ret-test design with CG	12 (3)	$M_{DLB} = 24.5 \pm 2.1$ $M_{DLR} = 24.5 \pm 2.1$ $M_{CG} = 23.8 \pm 3.9$	n. r.	8th Div.	Random and blocked DL to improve ball control and shooting accuracy was compared to blocked TL focusing on an ideal movement technique and error corrections.
Teaching Games for Understanding (TGFU; *n* = 5)							
Barquero-Ruiz et al. (2020)	SPA	Pre-test to post-test design	20 (1)[a]	$M = 9.74 \pm 0.79$	male and female	LL	The TGFU intervention focused on principles of play in defense and the attack. Each session started with a game form followed by a teaching for understanding period. Technical skills were practiced in drills before returning to a modified game form.
Harvey et al. (2010)	UK	Multiple baseline quasi-experimental design	34 (2)	$Range_{Firstyear}$: 14–15 $Range_{Varsity}$: 14–18	male	RC & CP	A TGFU intervention focusing on: "defending as a unit of three players" was conducted. SSGs, phases of play (e.g., offensive vs. defensive on one goal), and functional technical/tactical practice were applied.
Práxedes et al. (2016)	SPA	Quasi-experimental design with CG	18 (2)	$M = 10.7 \pm 0.60$	n. r.	YL	TGFU, based on modified games and questioning of the coach to improve the players' offensive tactical behavior, was compared to TL, primarily including technical drills that differed from real game situations.

(Continued)

TABLE 2 | Continued

Study	Country (ISO code)	Study design	Participants				Study description
			N (groups)	Age (years)	Sex	PL	
Práxedes Pizarro et al. (2017)	SPA	Intra-group quasi-experimental design	9 (1)	$M = 10.55 \pm 0.52$	Male	RL	A TGFU intervention, including a question-and-answer approach by the coach, to improve the players' decision-making and skill execution was applied. The complexity of the practice program increased progressively during the intervention period.
Sierra-Ríos et al. (2020)	SPA	Non-probabilistic inter-subject case design	30 (2)	$M_{TGFU} = 10.1 \pm 0.10$ $M_{DI} = 10.60 \pm 0.57$	n. r.	CP	TGFU, based on modified games, was compared to a direct instructional model based on technical and analytical exercises. Interventions aimed at improving players' on- and off-the-ball decision-making and skill execution.
Non-linear Pedagogy (NLP; *n* = 4)							
Práxedes et al. (2018a)	SPA	Quasi-experimental design	19 (2)	$M_{av} = 10.55 \pm 0.51$ $M_{low} = 10.66 \pm 0.50$	n. r.	av. & low	Two NLP interventions to develop players' decision-making and skill execution were applied. In the first intervention, SSGs with numerical superiority in attack (+1 player) were conducted. In the second intervention, SSGs with numerical equality were applied.
Práxedes et al. (2018b)	SPA	Quasi-experimental design with CG	19 (2)	$M_{NLP} = 10.55 \pm 0.51$ $M_{TL} = 11.77 \pm 0.66$	male	LL	The effects of a NLP-intervention, using SSGs with numerical superiority in the attack, were compared to TL, prioritizing technical components. The NLP exercises referred to a principle of play (e.g., maintaining possession of the ball).
Práxedes et al. (2019)	SPA	Intra-group quasi-experimental design	19 (1)	$M = 10.63 \pm 0.49$	n. r.	av. to low	Intervention based on the principles of NLP to improve the players' tactical decision-making and skill execution performance. SSCGs with numerical superiority were applied focusing on a tactical principle of play.
Roberts et al. (2020)	UK	Randomized cross-over trial	22 (2)	$M_{IG} = 16.4 \pm 0.4$ $M_{CG} = 16.1 \pm 0.2$	n. r.	YA	NLP, based on representative learning designs and perception-action couplings, was compared to a linear information-processing practice program regarding the promotion of attackers' individual learning objectives.

If authors did not sufficiently report the applied study design, the research group decided on an appropriate descriptive terminology. AL, Amateur Leagues; Av, average; CG, control group; Div., division; DL, differential learning; DLB, differential learning blocked; DLR, differential learning random; IG, intervention Group; LL, local level; NLP, non-linear pedagogy; n. r., not reported; PL, performance level; RL, regional level; TGFU, Teaching Games for Understanding; TL, traditional learning; YA, youth academy; YL, Spanish youth football league.

[a] *The 20 participants were randomly divided into two groups that practiced the same content, but the coaches changed between the groups to reduce clustering effects.*

either the practice design or coaching behavior and interventions were mostly not grounded in theoretical frameworks.

In the *first group of studies*, interventions were based on mainly three different theoretical and methodological underpinnings, namely DL, TGFU, and NLP (see **Table 2**). With nine studies, most utilized the DL approach. Of these nine studies, seven compared DL to traditional learning (TL) methods. Additionally, Coutinho et al. (2018) compared an enrichment program of DL to a non-active CG, and Gaspar et al. (2019) investigated acute effects after DL and TL sessions in a single group design.

TGFU was investigated in five studies. Two of these compared TGFU with TL, primarily applying technical drill practices supported by direct instructions (Práxedes et al., 2016; Sierra-Ríos et al., 2020). The further TGFU-studies without CGs only investigated within-group changes.

The remaining four studies in this first group investigated NLP. Roberts et al. (2020) compared NLP to promote youth academy attackers' individual learning objectives to a practice program grounded in information-processing theory. Práxedes et al. (2018a) compared NLP to a drill-based and technically focused TL program. Two studies without CG investigated the effects of NLP in a single-group design (Práxedes et al., 2019) or by comparing the effects in different performance groups (Práxedes et al., 2018b).

Within the *second group of studies*, specific aspects of practice and coaching were investigated (see **Table 3**). Only four studies reported skill acquisition frameworks or discussed the results in the light of theoretical considerations (Weigelt et al., 2000; Haaland and Hoff, 2003; Raastad et al., 2016; Schwab et al., 2019).

Sixteen studies focused on the design of practice tasks, whereby a multitude of different aspects and outcomes were pursued. For instance, seven studies examined the effects of drill-based practices on technical outcomes. Within these seven studies, two interventions only included deliberate technical drill practices (Weigelt et al., 2000; Montesano and Mazzeo, 2019). Others applied drill-based practices with subsequent game-based situations (e.g., Holt et al., 2012; Miranda et al., 2013) or combined it with coordination exercises (Boraczyński et al., 2019; Kösal et al., 2020).

Another five studies examined technical drill-practice programs focusing on the players' non-dominant leg performance (e.g., Teixeira et al., 2003). Finally, two studies examined game-based interventions (Radziminski et al., 2013; Arslan et al., 2020), and another two the effects of practicing with modified ball sizes (Bekris et al., 2012; Raastad et al., 2016).

Lastly, as the only study on coaches' behavior, Schwab et al. (2019) compared the effects of internal and external focus feedback for learning the knuckle ball freekick technique.

Methodological Approaches (Perspective 2)

Study Designs

Various study designs were used to investigate the influence of practice design and coaching behavior on soccer players' skill acquisition (see **Tables 2**, **3**). Single-group ($n = 7$; 20.0%), as well as multi-groups designs with two ($n = 19$; 54.3%), three ($n = 6$; 17.1%), four ($n = 2$; 5.7%), or six groups ($n = 1$; 2.9%) were found. Across the 27 controlled studies, different practice activities of CGs were found that need to be considered for interpreting intervention effects (see in detail **Supplementary Material III**). For example, most CGs practiced according to different approaches compared to the IG ($n = 17$) or participated in their regular ("usual care") practice ($n = 4$). Another three studies compared the interventions to non-active CGs. Only three cases were identified in which different practice or coaching methods as well as usual care or non-active CGs were investigated (e.g., Witkowski et al., 2011).

Measurements and Statistical Analyses

In 19 studies (54.3%) two measurement points were assessed (i.e., mostly pre- and post-test). Twelve studies (34.3%) conducted three, and three studies (11.4%) conducted four measurements (e.g., through intermediate measurements). Only six studies (17.1%) conducted a retention test to assess learning effects. Holt et al. (2012) observed the players' performances during the intervention in every session. Five studies that used systematic in-game observations averaged the performances from different matches as values for the respective measurement point (e.g., Práxedes Pizarro et al., 2017).

For assessing outcome effects, most studies used repeated-measures analyses of variance ($n = 14$, 40%). Four studies (11.4%) used multivariate analyses of variance and three studies (8.6%) applied t-tests. Another eight studies (22.9%) used non-parametric tests (e.g., U-test and Wilcoxon test). Two studies (5.7%) reported the players' improvements descriptively for each player (Holt et al., 2012; Montesano and Mazzeo, 2019) or used non-clinical versions of magnitude-based inferences (Coutinho et al., 2018; Gaspar et al., 2019).

Intervention Characteristics

The intervention duration varied substantially across studies (see **Table 5**). Large differences in the intervention duration in weeks ($M = 11.58$, $SD = 11.63$, $Mdn = 8$, [1, 48]), the number of sessions ($M = 29.41$, $SD = 34.27$, $Mdn = 15$, [1, 144]), as well as the sessions' duration in minutes ($M = 45.00$, $SD = 28.36$, $Mdn = 30$, [10, 120]) were found. Further, the number of sessions per week ranged from one to seven sessions ($M = 2.57$, $SD = 1.24$, $Mdn = 2$). Overall, four studies (11.4%) can be classified as short-, 20 studies (57.1%) as mid-, and 10 studies (28.6%) as long-term interventions. One study could not be categorized due to incomplete descriptions (Montesano and Mazzeo, 2019).

Participant Characteristics

In total, 992 participants were investigated in the reviewed studies, consisting of on average 28.34 participants per study ($SD = 17.16$, $Mdn = 20.00$, [5, 75]). The number of participants per group ranged from four to 30 ($M = 13.52$, $SD = 6.36$, $Mdn = 11.66$).

Most studies investigated male participants ($n = 17$, 48.6%), two studies (5.7%) examined both males and females (Raastad et al., 2016; Barquero-Ruiz et al., 2020) and 16 studies (45.7%) did not specify participants' sex. Whereas, four studies (11.4%)

TABLE 3 | Characteristics of studies investigating specific aspects of practice or coaching ($n = 17$).

Study	Country (ISO code)	Study design	Participants				Study description
			N (groups)	Age (years)	Sex	PL	
Effects of technical drill practice (with subsequent SSGs or coordination exercises; *n* = 7)							
Boraczyński et al. (2019)	POL	Single-center, parallel, partially group matched, controlled, and longitudinal design	75 (3)	Range: 10.1–11.9	male	n. r.	Proprioceptive-coordination training (PCT; including 24 technical exercises in combination with coordination exercises) on the players' soccer-specific motor performance was compared to a usual care and a non-active CG.
Holt et al. (2012)	UK	Single subject, multiple baseline experiment	5 (1)	Range: 10–12	male	YA	The effectiveness of the passing-square to promote awareness, passing, and first touch skills was investigated. Based on criteria for successful technical execution, the intervention included individual goal setting, peer-assessed feedback, and group contingency.
Kösal et al. (2020)	TUR	Pre- to post-test design with CG	45 (3)	Range: 10–13	male	n. r.	An additional practice program, including combined technical and coordination exercises to promote soccer-specific technical skills, was compared to regular and unstructured practice CGs.
Miranda et al. (2013)	BRA	Pre- to post-test design	13 (1)	Age = 17	n. r.	NL	The effects of a practice program, including position-specific technical and tactical exercises, as well as gameplay situations on the players' technical performance, were investigated.
Montesano and Mazzeo (2019)	ITA	Pre- to post-design with CG	20 (2)	$M = 16 \pm 0.5$	n. r.	CP	The effects of additional technical practice on the players' passing and shooting performance were investigated and compared to a CG without additional practice.
Weigelt et al. (2000)	UK	Pre- to post-test design with CG	20[a] (2)	Range: 19–20	male	IM	Learning and transfer effects of additional, individual feet-juggling practice without any specific guidance or learning strategies were investigated and compared to a non-active CG.
Zago et al. (2016)[b]	ITA	Pre- to post-test design with CG	20[b] (2)	$M = 11.5 \pm 0.3$	male	RL	Practice, including technical drills and phases of play situations by using tape matrix structures as three-dimensional spatio constraints was compared to a CG that participated in technical drills, SSGs, and situation games without such spatio constraints.
Practice to reduce lateral asymmetries or improve the non-dominant leg performance (*n* = 5)							
Guilherme et al. (2015a)	POR	Randomized cross-over design	50 (2)	$M = 9.54 \pm 1.86$	male	EL	The intervention period included additional drill-based practices for improving soccer-specific technical skills in the non-preferred leg. The control period did not include additional exercises.
Guilherme et al. (2015b)	POR	Pre- to post-test design with CG	71 (6)	$M = 14.44 \pm 1.04$ Range: 11–16	male	CP	The IG participated in drill-based and technically focused practice with a more frequent use of the non-dominant leg. The CG participated in a practice program by using both legs equally.
Haaland and Hoff (2003)	NOR	Pre- to post-test design with CG	39 (2)	Range: 15–21	male	CP	The IG participated in an increased volume of non-preferred leg practice within the team practice context. The effects were compared to a usual care CG.
Teixeira et al. (2003)	BRA	Pre- to post-test design with CG	24 (2)	Range: 12–14	n. r.	n. r.	The "non-preferred leg group" practiced 45 min in three out of five weekly sessions including drills and SSGs by only using the non-preferred leg. The "preferred-leg group" used both legs equally.

(Continued)

TABLE 3 | Continued

Study	Country (ISO code)	Study design	Participants				Study description
			N (groups)	Age (years)	Sex	PL	
Witkowski et al. (2011)	POL	Pre- to post-test design with CG	37 (3)	Age = 13	male	EL	One group predominantly used the non-dominant leg in technical drills, while another group used both legs equally. The effects were compared to a regular practice CG.
Effects of game-base practice programs (*n* = 2)							
Arslan et al. (2020)	TUR	Experimental parallel matched group design	20 (2)	$M = 14.2 \pm 0.5$	male	YA	The effects of game-based practice by using various forms of SSGs were compared to a running-based HIIT training program.
Radziminski et al. (2013)	POL	Pre- to post-test design with CG	20 (2)	$M_{SSG} = 15.1 \pm 0.67$ $M_{RG} = 15.0 \pm 0.46$	n. r.	n. r.	The effects of a practice program including various forms of 3v3 SSGs on the players' technical actions were investigated and compared to a running-based HIIT program.
Practice with modified ball sizes (*n* = 2)							
Bekris et al. (2012)	GRE	Pre- to post-test design with CG	54 (4)	$M = 11 \pm 0.6$	n. r.	n. r.	The effects of technical practice with a size-2 ball in different frequencies and with different content were compared to a CG that practiced with a size-4 ball.
Raastad et al. (2016)	NOR	Pre- to post-test design	17[c] (2)	$M = 16.6 \pm 0.93$ Range: 16–19	male and female	RL	Two groups practiced soccer juggling in two different conditions: One group practiced with a smaller size 1 ball. The other group practiced with a larger size 4 ball. The test ball was a size 3 ball.
Internal and external focus feedback (*n* = 1)							
Schwab et al. (2019)	GER	Pre- to post-, and ret-test design with CG	56 (4)	Adol.: U15-U17 Adults: n. r.	male	LL	The effects of external compared to internal focus feedback on learning the knuckle ball free-kick technique were investigated. Specific instructions were delivered after every third free kick.

If authors did not sufficiently report the study design, the research group decided on an appropriate descriptive terminology. Adol., adolescents; CG, control group; CP, competitive players; EG, experimental group; EL, elite level; EP = FD, first division; HIIT, High-intensity interval training; IG, intervention group; IM, intermediate Level; LL, Local level; LSPT, Loughborough Soccer Passing Test; NL, national level; n. r., not reported; RG, running group; RL, regional level; SSG, small-sided games; YA, youth academy.

[a] *Weigelt et al. (2000): the sample was reduced from 26 to 20 participants as two players did not participate in every session and goalkeepers were excluded from analyses.*

[b] *Zago et al. (2016): the sample was reduced from 26 to 20 participants that were able to participate in every session and test.*

[c] *Raastad et al. (2016): the sample was reduced from 22 to 17 participants that completed the practice sessions and were not injured.*

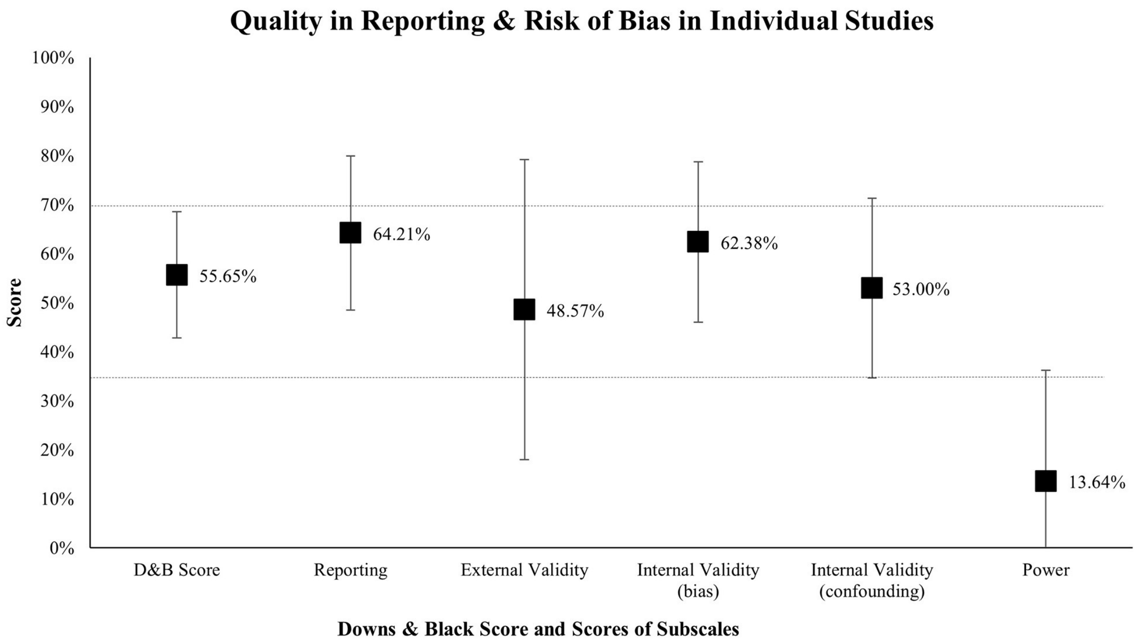


FIGURE 2 | Quality in reporting and risk of bias in individual studies. D&B Score, Downs and Black score (all items). Notes: Results are presented as means with error bars that represent the standard deviation. The dashed lines show thresholds for low (≤ 35%) and high (≥ 70%) scores. It must be considered that the subscales *external validity* and *power* were calculated from only three and two items, respectively.

investigated adult players and two studies (5.7%) examined both youths and adults, most studies utilized youth soccer players (82.9%, $n = 29$). Thereby, most studies were conducted with participants between the age of 11 to 15 ($n = 20$).

Twentynine studies reported the performance level of the sample (82.9%; see **Tables 2**, **3**). A wide range of terminologies was found, in some cases corresponding to national league systems. Regional level players (incl. descriptions such as "moderate level") were most frequently examined ($n = 11$, 31.4%), followed by studies with youth academy or national level players ($n = 6$, 17.1%) and local (or "low") level players ($n = 4$; 11.4%). Two studies compared the effects of interventions with players on different performance levels (Harvey et al., 2010; Práxedes et al., 2018b). Studies with adult participants investigated players from regional levels (i.e., 5th to 8th divisions). The youth and adult players in Schwab et al.'s (2019) study were recruited from local levels, Haaland and Hoff (2003) investigated competitive players.

Instruments

To assess outcome effects, skill tests were used in 22 studies (62.9%) and systematic observations were applied in 13 studies (37.1%; see in detail **Supplementary Material III**). No study used both kinds of assessments. The systematic observations occurred in different contexts that included in-game observations during practice ($n = 7$), competition ($n = 5$), or technical drills ($n = 1$). The Game Performance Evaluation Tool (GPET; García López et al., 2013) was most frequently employed for in-game observations ($n = 6$), followed by the Game Performance Assessment Instrument (GPAI; Oslin et al., 1998; $n = 2$), the Creative Behavior Assessment in Team Sports (CBATS; Santos et al., 2017; $n = 2$), and the System of Assessment of Functional Asymmetry of the Lower Limbs in Football (SAFALL-FOOT; Guilherme et al., 2012; $n = 2$). SSGs, ranging from 3v3 to 8v8, were utilized for systematic observations.

Quality in Reporting and Risk of Bias

The results for the assessment of the quality in reporting and risk of bias in individual studies are presented in **Figure 2** (see in detail **Supplementary Material II**). On average, the score of the Downs and Black Checklist reveals a moderate methodological quality ($M = 55.65\%$, $SD = 12.86\%$, $Mdn = 57.69\%$). There are, however, large differences between studies ranging from 30.77% to 78.57% of the total score (2x low score, 5x good score). Most papers lacked a sufficient report of principal confounders (item 5), only four studies (11.4%) met this criterion. To assess outcome effects, 10 studies (28.6%) used assessments that were not evaluated regarding their reliability (item 20). Moreover, very few studies conducted a priori sample size estimations ($n = 5$, 14.3%), leading to an overall low statistical power.

The TIDieR displays large differences across studies with an average score of 59.11% ($SD = 22.52\%$, $Mdn = 66.67\%$, [11.11, 100]). Even the two studies that reached 100% did not differentiate for every single session but provided an overview of the intervention content across sessions (Zago et al., 2016; Roberts et al., 2020). Another 20 studies (57.1%) presented the procedures in a manner that permits the replication of at least parts of interventions. Lastly, 15 studies (42.9%) controlled as to whether the intervention was delivered as intended, but only nine studies reported underlying criteria of observation.

Outcome Variables

A list of examined outcome variables is provided in **Table 4**. In total, 150 outcome variables were investigated. However, 123 different variants for operationalization (e.g., different skill tests) and different contexts of assessments (e.g., game formats for systematic observations) lead to a highly heterogeneous conglomeration of outcomes. Moreover, six studies employed overall performance scores which included perceptual-motor and perceptual-cognitive characteristics. Yet, none of these scores were calculated based on variables assessed in comparable contexts or with identical equations.

On average, 4.29 ($SD = 3.39$, $Mdn = 4$, [1, 20]) outcome variables were investigated per study. Thirty four studies (97.2%) assessed perceptual-motor outcomes, such as the players' technical performance in skill tests or in-game technical executions. Eleven studies (31.4%) assessed perceptual-cognitive outcomes, such as the divergent (i.e., creativity) or convergent (i.e., decision-making) tactical performance. Two studies examined tactical behavior in defense (Harvey et al., 2010; Barquero-Ruiz et al., 2020), while all other studies addressed aspects in the attack.

Perceptual-motor outcomes, such as shooting accuracy or dribbling were most often collected via skill tests ($n = 22$ studies). Technical skill execution, assessed with the GPET or GPAI, was the most frequently examined in-game variable ($n = 8$ studies). Five studies distinguished between different techniques (i.e., in-game passes or dribbles), while others reported cumulative variables.

Decision-making was the most often examined perceptual-cognitive outcome ($n = 9$ studies). Práxedes et al. (2016, 2018a,b, 2019), Práxedes Pizarro et al. (2017), and Roberts et al. (2020) reported whether the decisions occurred in different contexts (i.e., passing, dribbling, or shooting) while others only provided accumulated performance values. Lastly, in-game creativity was examined in two studies (Coutinho et al., 2018; Santos et al., 2018).

TABLE 4 | Soccer-specific outcome variables ($n = 150$) from perceptual-motor and perceptual-cognitive skill domains.

Perceptual-motor domain ($n = 105; 85$)	**Perceptual-cognitive domain ($n = 45; 38$)**
Technical performance (skill tests):	*Tactical decision-making (in-game):*
Shooting/kicking/striking ($n = 25$; 16)	Decision-making cumulative ($n = 9$; 9)
Dribbling ($n = 19$; 17)	Passing ($n = 5$; 2)
Passing ($n = 15$; 14)	Dribbling ($n = 3$; 2)
Juggling ($n = 8$; 7)	
Ball reception/control ($n = 7$; 6)	*Decision-making (skill test):*
Turns ($n = 2$; 2)	Goal shooting ($n = 1$; 1)
Awareness ($n = 1$; 1)	
Ball bouncing ($n = 1$; 1)	*Defensive tactical behavior (in-game):*
Balance with ball ($n = 1$; 1)	Adjust ($n = 2$; 2)
Heading ($n = 1$; 1)	Covers ($n = 2$; 2)
1v1 ($n = 1$; 1)	
Execution time (LSST; $n = 1$; 1)	*Creativity (in-game):*
	Attempts ($n = 5$; 4)
Technical skill execution (in-game):	Fluency ($n = 5$; 4)
Skill execution cumulative ($n = 8$; 8)	Versatility ($n = 5$; 4)
Passes ($n = 5$; 2)	Fails ($n = 4$; 4)
Dribbles ($n = 4$; 3)	Originality ($n = 4$; 4)
(Goal) shots (2; 2)	
Preferred foot performance ($n = 2$; 1)	
Non-preferred foot performance ($n = 2$; 1)	

Results in brackets represent the n of investigated variables (first number) and the n of different operationalizations (second number). Performance scores that were calculated from both perceptual-motor and perceptual-cognitive skill domains (n = 6) were not displayed in this table. LSST, Loughborough Shooting Skill Test.

Effectiveness of Interventions (Perspective 3)

Inferences on the effectiveness of interventions can only be drawn from the 27 controlled studies. The main results were narratively synthesized in **Table 5**. A summary of results for studies without a CG is provided in **Supplementary Material IV**. For the quantitative synthesis of controlled studies, 51 effect sizes (26 significant; 50.98%) for perceptual-motor outcomes and 32 effect sizes (11 significant; 34.38%) for perceptual-cognitive outcomes could be recalculated (see **Table 6**). Given the large differences across studies (e.g., practice activities of CGs) a detailed analysis of individual studies is necessary.

Effectiveness of Instructional Approaches

Differential Learning

Comparisons of DL and TL led to ambivalent results across studies (see **Table 6**). Most studies assessed the effectiveness in the acquisition phase regarding precision-based technical variables (e.g., shooting accuracy). Only three out of thirteen effects reached significance and, thus, reveal greater effectiveness of DL [$Mdn(d) = 0.45$; $-0.15 \leq d \leq 2.37$]. Regarding time-based tests (i.e., dribbling speed), Ozuak and Çaglayan (2019) found two significant effects when supplemental DL was compared to a usual care CG ($0.49 \leq d \leq 1.22$). Hence, Bozkurt (2018) did not confirm the greater effectiveness of DL compared to TL in dribbling ($d = 0.11$). Only two studies applied retention tests to assess learning effects in goal shooting precision [Schöllhorn et al., 2006 (study 1), 2012]. In both studies, significantly greater effects in favor of DL were found, although Schöllhorn et al. (2012) only found a statistically relevant retention-effect for random DL [$Mdn(d) = 1.14$; $0.64 \leq d \leq 1.97$; two of three significant].

Coutinho et al. (2018) compared DL, using SSGs and technical drills, to a non-active group. Non-clinical magnitude-based inferences displayed greater acquisition effects for DL in U15 players regarding in-game dribbles and shots, as well as creative components fluency and versatility. In U17, greater effectiveness was only found in the technical shooting performance. Santos et al. (2018) found positive effects in favor of game-based DL compared to a game-based CG in few creative components. More

TABLE 5 | Narrative synthesis of the effectiveness of interventions in controlled designs ($n = 27$).

Study	Groups	Intervention duration		Statistical analysis	Outcome variables	Main results
		Sessions (min. p. session)	Weeks			
Differential Learning (DL; *n* = 8)						
Bozkurt (2018)[a]	- DL ($n = 6$) - TL ($n = 6$)	12 (20)	4	U-Test and Wilcoxon	*Skill tests:* - passing - dribbling - feet-juggling	No significant differences between groups in technical outcomes were found at pre- or post-test. Thus, neither DL nor TL was found to be more effective for promoting soccer-specific techniques.
Coutinho et al. (2018)[a]	- DL U15 ($n = 9$) - DL U17 ($n = 6$) - Usual care U15 ($n = 9$) - Usual care U17 ($n = 6$)	20 (25)	10	Non-clinical magnitude-based inferences	*In-game:* - Technical performance (dribbles, shots, and goals) - Creativity (fluency, attempts, and versatility)	In U15, greater improvements after DL compared to TL in all technical variables, fluency, and versatility were found. In U17, DL only achieved greater improvements in shooting, while no effects in further outcomes were found.
Hossner et al. (2016)	- DL ($n = 9$) - DL and FB ($n = 9$) - TL ($n = 10$)	12 (30)	6	Repeated measures ANOVA	*Skill-test:* - Shooting accuracy	No significant interactions between the DL and TL groups, as well as DL with and without feedback groups, were found.
Ozuak and Çaglayan (2019)	- DL ($n = 26$) - Usual care ($n = 26$)	24 (40–50)	8	U-Test and Wilcoxon	*Skill tests:* - Creative speed test - Dribbling - Juggling - Passing	The DL group achieved significantly greater improvements in creative speed and ball dribbling tests. No significant differences compared to the usual care group were found in juggling and passing.
Santos et al. (2018)	- DL U13 ($n = 10$) - DL U15 ($n = 10$) - TL U13 ($n = 10$) - TL U15 ($n = 10$)	40 (30)	20	ANCOVA	*In-game:* - Creativity (fails, attempts, fluency, versatility, and originality) in passes, dribbles, and shots	DL led to significantly greater effects in few creative components in both ages compared to TL. A decrease in fails in both ages was found. Significant differences were also found in attempts, originality, and most stressed in versatility. More significant and higher effect sizes were found in the U13 age group.
Schöllhorn et al. (2006; study 1)	- DL ($n = 8$) - TL ($n = 8$)	12 (20–40)	4	U-test	*Skill test:* - Passing accuracy with non-dominant foot	Significant differences at post-test between groups reveal a greater effectiveness of DL in non-dominant foot passing accuracy compared to TL.
Schöllhorn et al. (2006; study 2)	- DL ($n = 8$) - TL ($n = 8$)	12 (25)	6	U-test	*Skill test:* - Shooting accuracy	Significantly greater improvements after DL in shooting accuracy were found. DL also outperformed TL after 1-year retention period.
Schöllhorn et al. (2012)	- DL blocked ($n = 4$) - DL random ($n = 4$) - TL ($n = 4$)	8 (25)	4	H-Test	*Skill tests:* - Ball control - Shooting accuracy	In the acquisition phase, only the blocked DL achieved greater improvements in goal shooting. At retention-test only the random DL outperformed TL. No differences in ball control were found.
Teaching Games for Understanding (TGFU; *n* = 2)						
Práxedes et al. (2016)	- TGFU ($n = 9$) - TL ($n = 9$)	21 (60)	12	MANOVA	*In-game:* - Decision-making (passing and dribbling) - Skill execution (passing and dribbling)	TGFU was found to be significantly more effective than TL in promoting decision-making (passing and dribbling). The only significant difference in the execution variables in favor of TGFU was found for passes.

(Continued)

TABLE 5 | Continued

Study	Groups	Intervention duration		Statistical analysis	Outcome variables	Main results
		Sessions (min. p. session)	**Weeks**			
Sierra-Ríos et al. (2020)[a]	- TGFU ($n = 15$) - DI ($n = 15$)	12 (80)	6	MANCOVA	*In-game:* - Decisions (on- and off-the-ball) - Executions (on- and off-the-ball)	A significantly greater reduction in the number of unsuccessful on-the-ball executions, a decrease in off-the-ball errors, and more successful off-the-ball actions after TGFU were present. No differences in the successful on-the-ball performance were found.
Non-linear Pedagogy (NLP; $n = 2$)						
Práxedes et al. (2018a)	- NLP ($n = 10$) - TL ($n = 9$)	14 (60)	7	MANOVA	*In-game:* - Decision-making (passing and dribbling) - Skill execution (passing and dribbling)	No significant group × time interaction was found. However, at post-test, the NLP group significantly outperformed the TL group in passing decisions and executions. No differences were found in dribbles.
Roberts et al. (2020)	- NLP ($n = 11$) - IP ($n = 11$)	8 (60)	4	U-Test and Wilcoxon	*Skill-test:* - Strong foot finishing - Weak foot finishing−1v1 - Decision-making	Significantly greater improvements in the NLP group compared to the IP group were found in 1v1 and decision-making skills. No significant differences were found in the technical shooting proficiency or the execution time.
Effects of technical drill practice (with additional SSGs or coordination training; $n = 5$)						
Boraczyński et al. (2019)[a]	- PCT ($n = 26$) - Usual care ($n = 27$) - Non-active ($n = 22$)	n.r. (30 min. add. practice)	12 months	Repeated measures ANOVA	*Skill tests (dom. leg):* - Turning the ball backward - Slalom dribbling - Static balance with a ball - Kicking accuracy	Only in the static balance test with a ball, a group × time interaction was found due to greater improvements in the PCT group at peri- and post-test compared to the usual care group.
Kösal et al. (2020)	- Coordination ($n = 15$) - Usual care ($n = 15$) - Unstructured ($n = 15$)	30 (30 min. add. practice)	10	Repeated measures ANOVA	*Skill tests:* - Dribbling - Passing - Shooting - Ball bouncing - Wall volley	The coordination group improved in all variables and fewer within-group effects were found compared to the usual care group. The unstructured practice group did not improve in any variable. However, no interaction effects were reported.
Montesano and Mazzeo (2019)	- Add. practice ($n = 9$) - Usual care ($n = 9$)	n. r. (60-80)	n. r.	Descriptive analyses	*Skill tests:* - Passing - Shooting	Both groups descriptively improved in successful passes and goal shots. Descriptively greater improvements were found after add. practice.
Weigelt et al. (2000)	- Intervention ($n = 10$) - Non-active ($n = 10$)	28 (10)	4	MANOVA	*Skill-tests:* - Juggling with feet - Juggling with Knees - Ball control strong foot - Ball control weak foot	A significant time x group effect due to improvements in knee juggling and ball control with both feet (transfer effect), as well as a trend toward better feet-juggling performance, was found.
Zago et al. (2016)[a]	- Intervention ($n = 10$) - Control ($n = 10$)	38 (¼ to ½ of the average session time of 98 min)	22	Repeated measures ANOVA	*Skill tests:* - LSPT - Shuttle dribble test - Slalom dribble test	A significant time × group interaction was found in the LSPT performance (execution time) due to greater improvements in the IG. No significant interactions in other variables were found.

(Continued)

TABLE 5 | Continued

Study	Groups	Intervention duration		Statistical analysis	Outcome variables	Main results
		Sessions (min. p. session)	**Weeks**			
Practice to reduce lateral asymmetries or improve the non-dominant leg performance (n = 5)						
Guilherme et al. (2015a)	Cross-over: - Group 1 (n = 26) - Group 2 (n = 24)	48 (20)	16	Repeated measures ANOVA	*In-game:* - Preferred foot performance utilization - Non-preferred foot performance utilization	The non-dom. leg practice significantly increased the utilization rate during match-play. The interruption of the additional practice during the retention period partially reversed this effect.
Guilherme et al. (2015b)	- NPL U13 (n = 12) - NPL U15 (n = 11) - NPL U17 (n = 12) - CG U13 (n = 12) - CG U15 (n = 12) - CG U17 (n = 12)	108 (20)	36	Repeated measures ANOVA	*In-game:* - Preferred foot performance utilization - Non-preferred foot performance utilization	The experimental practice program led to a significantly greater utilization rate of the non-preferred leg during match-play, while the use of the preferred leg significantly decreased.
Haaland and Hoff (2003)[a]	- Intervention (n = 18) - Usual care (n = 21)	n. r. (n. r.)	8	Repeated measures ANOVA	*Skill tests:* - Slalom dribbling - Ball control (chest) and volley shooting accuracy - One-touch passing accuracy	Significantly greater improvements in the intervention group compared to the CG in both the dominant and non-dominant legs in dribbling, volley shooting, and one-touch passing variables.
Teixeira et al. (2003)	- 12-year PL (n = n. r.) - 13-year PL (n = n. r.) - 15-year PL (n = n. r.) - 12-year NPL (n = n. r.) - 13-year NPL (n = n. r.) - 15-year NPL (n = n. r.)	80 (45)	16	Repeated measures ANOVA	*Skill tests:* - Speed of dribbling - Kicking for accuracy - Kicking for force	Only in speed dribbling, the lateral asymmetry was significantly reduced from pre- to post-test in the non-preferred-leg group. In other variables, no significant differences between groups were found due to improvements in both the preferred and non-preferred-leg groups.
Witkowski et al. (2011)	- Non-dom-leg (n = n. r.) - Both legs (n = n. r.) - Usual care (n = n. r.)	144 (n. r.)	12 months	t-tests	*Skill tests:* - Dribbling - Ball striking	Both the non-dominant and dominant leg groups achieved greater improvements in technical outcomes compared to the usual care group.
Effects of game-based practice programs (n = 2)						
Arslan et al. (2020)	- SSG (n = 10) - HIIT (n = 10)	10 (10–18)	5	Repeated measures ANOVA	*Skill tests:* - Dribbling speed - Zigzag agility with ball	Both groups improved in their technical performance from pre- to post-test. Higher within-group effects were found in the SSG group. No interaction effects were reported.

(Continued)

TABLE 5 | Continued

Study	Groups	Intervention duration		Statistical analysis	Outcome variables	Main results
		Sessions (min. p. session)	Weeks			
Radziminski et al. (2013)[a]	- SSG ($n = 9$) - Running ($n = 10$)	16 (90)	8	Repeated measures ANOVA	*Skill tests:* - Juggling - Rotation pass - Passing - Dribbling - Heading, - Bench passing - Shooting accuracy	No significant group × time interaction was found. The performance increased in both the SSG and Running groups.
Practice with modified ball sizes ($n = 2$)						
Bekris et al. (2012)	- Competitive ($n = 12$) - 20-min ($n = 13$) - 30-min ($n = 14$) - Control ($n = 15$)	12 (20–30)	n. r.	Repeated measures ANOVA	*Skill tests:* - Passing - Juggling - Running with the ball - Turning	Significantly greater improvements in juggling, running with the ball, and turning in all intervention groups compared to the CG were reported. No effects in passing were found.
Raastad et al. (2016)	- Smaller ball ($n = 11$) - Larger ball ($n = 11$)	24 (10)	6	Repeated measures ANOVA	*Skill tests:* - Juggling - Ball reception	The ball juggling performance of both groups increased from pre- to post-test, but no interaction effect regarding transfer effects was found.
Internal and external focus feedback ($n = 1$)						
Schwab et al. (2019)	- Internal adol. ($n = 10$) - Internal adult ($n = 18$) - External adol. ($n = 10$) - External adult ($n = 18$)	6 (20)	3	Repeated measures ANOVA	*Skill test:* - Rotational ball velocity - Linear ball velocity	External focus feedback led to a significantly greater reduction in the rotational ball velocity from pre- to post and pre- to ret-test. No effects on the linear ball velocity were found.

Add., additional; Adol., adolescent; DI, Direct Instruction; DL, Differential Learning; DL and FB, Differential Learning and Feedback; HIIT, High-Intensity Interval Training; LSST, Loughborough Shooting Skill Test; TL, Traditional Learning; TGFU, Teaching Games for Understanding; NPL, non-preferred leg; PL, preferred leg; SSG, small-sided games.

[a]*Further variables, that do not correspond to the perceptual-motor or perceptual-cognitive skill domains (e.g., physiological outcomes), were investigated in the study.*

[b]*Arslan et al. (2020), Kösal et al. (2020), and Witkowski et al. (2011) did not conduct or sufficiently report interaction effects. Thus, the narrative synthesis is limited to the comparison within group time effects between groups.*

TABLE 6 | Recalculated effect sizes for perceptual-motor and perceptual-cognitive outcomes from controlled designs.

Category (*N* of studies)	Study design		*N* of effects		Perceptual-motor domain			Perceptual-cognitive domain		
	UCD	CD	*d*	d_{ppc2}	*N* of effects (% sig.)	Median	Range	*N* of effects (% sig.)	Median	Range
DL (9)[a]	1	8	4	43	21 (33.33%)	0.49	−0.15–2.37	26 (23.08%)	0.45	−0.23–1.92
TGFU (5)	3	2	0	10	6 (66.67%)	1.98	0.45–2.80	4 (100%)	1.89	0.90–2.62
NLP (4)[b]	2	2	2	5	5 (20.00%)	0.58	0.17–1.05	2 (50.00%)	0.83	0.60–1.05
Drill-based P. (7)	2	5	6	0	6 (50.00%)	0.73	0.12–1.20	–	–	–
Non-dom. Leg (5)[c]	0	5	10	0	10 (100%)	1.16	0.82–2.91	–	–	–
Game-based P. (2)[d]	0	2	0	0	–	–	–	–	–	–
Mod. ball sizes (2)	0	2	1	0	1 (0.00%)	0.36	–	–	–	–
Instructions (1)	0	1	2	0	2 (50.00%)	0.35	0.11–0.59	–	–	–
Total (35)	8	27	25	58	51 (50.98%)	0.74	−0.15–2.91	32 (34.38%)	0.61	−0.23–2.62

All effect sizes comparing intervention and control groups from pre- to post, but also from pre- to ret-test were included in this overview. CD, controlled designs; UCD, uncontrolled designs. P., Practice, sig., significant. Effect sizes from studies on instructional approaches are provided in the upper half of the table. Effect sizes from studies on specific aspects of practice or coaching are presented below.

[a] *Schöllhorn et al. (2012) compared random DL, blocked DL, and TL groups. Only the effects for the comparisons of the random and blocked DL groups compared to the TL group, but not for the comparisons of random and blocked DL groups, were considered.*

[b] *Práxedes et al. (2018b) used a multivariate analysis of variance including both the perceptual-motor (i.e., skill execution in passing and dribbling) and perceptual-cognitive outcomes (i.e., decision making in passing and dribbling). The non-significant effect (d = 1.05) is once included in the perceptual-motor and perceptual-cognitive domain as no differentiation was possible based on the reported results.*

[c] *Guilherme et al. (2015a,b) reported the effects of the utilization rate for both the dominant and non-dominant leg. As a reduction of lateral asymmetries was intended, the higher utilization rate of the non-dominant leg, but also the lower utilization rate of the dominant leg is displayed as a positive effect.*

[d] *No effects for game-based studies could be recalculated due to missing data.*

significant and slightly higher effects in the U13 [$Mdn(d) = 0.40$; $0 \leq d \leq 1.08$; four of 15 significant] compared to U15 [$Mdn(d) = 0.27$; $-0.08 \leq d \leq 1.91$; two of 15 significant] were found. The largest and most frequent effects were present for versatility in passes and dribbles [$Mdn(d) = 1.05$; $-0.02 \leq d \leq 1.92$; three of four significant]. Further, DL significantly outperformed TL regarding originality in passes in both ages ($0.45 \leq d \leq 0.68$) and fewer fails in dribbles in U13 ($d = 0.87$; Santos et al., 2018).

To sum up, two studies provide support on the general effectiveness of DL in at least a few technical or tactical outcomes (Coutinho et al., 2018; Ozuak and Çaglayan, 2019). Results on the relative effectiveness of DL compared to TL regarding the promotion of soccer-specific techniques are, however, ambivalent. Yet, no study found significantly greater improvements after TL. In terms of creativity, Santos et al. (2018) indicate the potential of DL to encourage versatility and originality compared to other game-based models.

Teaching Games for Understanding

The TGFU approach was compared to TL, primarily including decontextualized drills (Práxedes et al., 2016; Sierra-Ríos et al., 2020). Práxedes et al. (2016) found strong effects in favor of TGFU in decision-making for passes and dribbles ($0.90 \leq d \leq 1.40$; two of two significant). A significant effect in the execution variables was present for passes ($d = 1.10$), but not for dribbles ($d = 0.45$). In the study by Sierra-Ríos et al. (2020), TGFU outperformed the direct instruction group regarding significantly more successful off-the-ball decisions, and executions ($2.62 \leq d \leq 2.80$; 2 of 2 significant), as well as less unsuccessful actions ($2.37 \leq d \leq 2.48$; 2 of 2 significant). Regarding on-the-ball variables, only significantly fewer inefficient technical actions support the greater effectiveness of TGFU ($d = 2.48$), but not more efficient technical executions were found.

Non-linear Pedagogy

Práxedes et al. (2018a) compared NLP to TL group that prioritized technical components. NLP was altogether not significantly more effective than TL ($d = 1.05$).[3] However, at post-test, the NLP group significantly outperformed the TL group in passing decisions and executions. No significant differences in dribble variables were found. Roberts et al. (2020) compared NLP to a practice program based on information-processing theory

[3] Práxedes et al. (2018b) used multivariate statistics and did not report baseline statistics so that only the MANOVA effect, considering both perceptual-motor and perceptual-cognitive outcomes, can be provided.

and found greater improvements after NLP in 1v1 ($d = 0.74$) and decision-making skills ($d = 0.60$). No significant differences occurred in technical variables [$Mdn(d) = 0.44; 0.17 \leq d \leq 0.58$].

Effectiveness of Interventions on Specific Aspects of Practice or Coaching

Generally, the low number of effect sizes within this second group, as well as an often limited content-related comparability of studies impede an accumulated report. For game-based interventions, even no effect size could be recalculated.

Sixteen controlled studies investigated multiple aspects of the practice design to promote technical skills. Regarding *technical drill practices (with subsequent SSGs),* Zago et al. (2016) found that the use of tape-matrix structures as spatio temporal constraints for both, technical drills, and phases of play situations, led to a significantly faster passing execution time compared to a group that practiced without such constraints ($d = 1.05$). No interactions in other precision- or time-based technical outcomes occurred [$Mdn(d) = 0.14; 0.12 \leq d \leq 0.94$]. Weigelt et al. (2000) found a significant interaction of deliberate juggling practice compared to a non-active CG, resulting from improvements in knee-juggling, but also positive transfer effects to ball control performance ($d = 1.20$). Such positive transfer to ball control was not confirmed by Raastad et al. (2016), additionally, no differences occurred in deliberate juggling practice with smaller or larger balls ($d = 0.36$).

The *non-dominant leg practice* interventions consistently led to greater effects compared to CGs. Guilherme et al. (2015a,b) found that additional drill-based non-dominant leg practice led to a higher utilization rate in game-based situations compared to non-additional practice CGs ($2.31 \leq d \leq 2.91$; two of two significant). The decrease in the preferred leg utilization rate reveals fewer lateral asymmetries during match-play ($1.40 \leq d \leq 2.31$; two of two significant). Haaland and Hoff (2003) further showed that the predominant use of the non-dominant leg within team practice led to improvements in both the non-dominant [$Mdn(d) = 0.93; 0.88 \leq d \leq 1.32$; three of three significant] and dominant legs [$Mdn(d) = 0.95; 0.82 \leq d \leq 0.99$; three of three significant] compared to a usual care CG.

In the only study on *coaches' instructions* (Schwab et al., 2019), external focus feedback led to greater improvements compared to internal focus feedback in the knuckle-ball technique due to a reduction in the rotational ball velocity ($d = 0.59$). No differences were found in the linear ball velocity ($d = 0.11$).

DISCUSSION

Enhancing soccer players' skill acquisition is an essential part of coaches' work that should be supported by evidence-based knowledge to identify the most effective practice and coaching methods. Thirty-five studies were reviewed to pool the growing body of research investigating perceptual-motor and perceptual-cognitive skills as outcomes of interventions anchored in pitch-based settings. Two groups of studies were identified within the present research. In the first group, theory-driven instructional approaches were investigated and compared to non-active CGs or active controls practicing according to differing methodologies. In the second group, specific aspects of the practice design or coaches' instructions were examined, but interventions were often not explicitly embedded within skill acquisition paradigms. In both groups, methodological differences in terms of the study designs, practice activities of CGs, outcome variables, as well as research quality challenge the comparability of the respective study results. Thus, interpreting the potential of the investigated methodologies requires a detailed discussion of underlying theoretical frameworks, derived principles to practice and coaching, as well as studies' methodological characteristics and limitations.

Theoretical Perspectives

Regarding studies on instructional approaches, underlying frameworks of self-organization approaches DL (i.e., dynamical systems theory) and NLP (i.e., ecological dynamics), as well as corresponding principles for practice and coaching, were clearly stated. Allocating TGFU solely based on skill acquisition theory seems inappropriate as it emerged from "an educative perspective rather than approaching it from purely the field of sports science/skill acquisition" (Harvey et al., 2018; p. 175). In contrast to the underpinnings of IGs' practice, theoretical frameworks of CGs were only stated in a few studies (e.g., Schöllhorn et al., 2006; Roberts et al., 2020). In many studies on TGFU and NLP, the respective CGs' practice was not explicitly linked to a cognitive, information-processing approach to skill acquisition. Instead, CGs were defined on a practical rather than on a theoretical level by "prioritizing the technical component" (Práxedes Pizarro et al., 2017, p. 187) while IGs practiced both technical and tactical aspects of play. Similarly, not withstanding the outlined exceptions, the vast number of studies on specific aspects did not design their interventions based on skill acquisition theory. Thus, many of the reviewed studies only contribute to a practical discussion and do not allow inferences on the explanatory value of skill acquisition theories, and thereto derived methodological conclusions on how to effectively design and deliver practice and coaching.

Practical Implementation

Typically, technical practices following an information-processing viewpoint targeted the development of "ideal movement archetypes" (Schöllhorn et al., 2012, p. 104) mostly through decontextualized drills. When aspiring to tactical objectives, practices were sometimes enriched by subsequent game-based situations to apply the to-be-learned skills in game-realistic contexts. Coaches acted as "expert[s] leading participants to a series of pre-determined outcomes" (Roberts et al., 2020, p. 1456) by using a high number of verbal instructions and demonstrations. However, it was often not clearly outlined if, when, and how the decomposed technical practice was linked to tactical aspects within the sessions' microstructure and the interventions' periodization.

Regarding DL, a variety of implementations regarding both technically focused drill-based and game-based interventions were utilized. For instance, "superfluous exercises" (Schöllhorn et al., 2006, p. 191) were added to target drills (e.g., additional body movements) or random modifications of SSGs (e.g., equipment or rules) were applied to create noise throughout the learning process. Nevertheless, a hitherto unresolved problem is the lack of metrics for quantifying variability ("noise") limiting opportunities for replications and practical recommendations for coaches' work.

Both NLP and TGFU interventions primarily include game-based activities and in some cases applied skill practice tasks aiming at a rather natural variability within and between skills. This was mostly achieved through simplified "contexts of play" (Práxedes et al., 2019, p. 335) such as numerical superiority SSGs. These methodological similarities are in line with those outlined in the literature on TGFU and the CLA that is underpinned by principles of NLP (Renshaw et al., 2016; Harvey et al., 2018). Nevertheless, specific differences grounded in the respective theoretical underpinnings were often difficult to identify. Few studies reported in detail how coaches guided players in TGFU in an explicit process through reflective questions (Barquero-Ruiz et al., 2020). Otherwise, more implicit strategies in manipulating constraints to promote "strong functional couplings of information and movement" (Roberts et al., 2020, p. 1456) were described for NLP interventions. Yet, the implementation of specific strategies within a defined context, the triggers for their use, as well as the dose were scarcely specified. Such details in the light of the targeted outcomes are, however, particularly important to achieve conceptual clarity and reduce misinterpretations (Cope and Cushion, 2020).

Critical Appraisal of Methodological Study Characteristics

The present review faces often outlined methodological challenges in systematic reviews and meta-analyses of intervention research, such as large methodological diversity across studies, outcome variables, and practice activities of CGs (Abad Robles et al., 2020; Silva et al., 2021; Tassignon et al., 2021). Besides that, the quality in reporting and risk of bias, as well as the quality of intervention description largely differed across studies and some general limitations in the present body of research were uncovered. These limitations need to be critically discussed to ensure a careful and reflected interpretation of the interventions' effectiveness.

Study Designs and Intervention Characteristics

Studies without a CG need to be necessarily excluded from analyses on the effectiveness as the outcomes could be biased by various confounding factors. Even within controlled studies, the research designs varied substantially, limiting the comparability of results. Caution is also required when comparing the effects as different types of CGs were identified (see in detail **Supplementary Material III**). While comparisons to non-active CGs only allow conclusions on the general effectiveness of interventions, usual-care CGs provide evidence on whether interventions could improve current practice (Smelt et al., 2010). Attention is advised when CGs mainly practice technical aspects while IGs focus on both technical and tactical content, in particular when both technical and tactical outcomes were assessed through systematic in-game observations. Such comparisons neither allow a theory-led discussion of results, nor enable conclusions on the effectiveness of investigated approaches in relation to other methodologies.

The only studies which allow for conclusions on the relative effectiveness of practice and coaching methods are those that explicitly state theoretical and methodological principles of CGs and by approaching similar practice objectives. However, most studies did not include additional non-active CGs so that improvements in both groups could not be interpreted (e.g., Hossner et al., 2016). Yet, ensuring both sufficient statistical power and including additional no-training CGs could be particularly difficult in applied experimental settings. Nevertheless, in line with Vater et al. (2021), including at least a non-active CG can be seen as the minimum requirement to ensure sufficient quality of evidence. Potentially, randomized crossover designs—as chosen by Roberts et al. (2020)—provide solutions that every player can profit from interventions by simultaneously controlling intervention effects.

Primarily, studies focused on performance changes (i.e., temporary fluctuations in behavior), but not on learning effects (i.e., permanent changes over time; Soderstrom and Bjork, 2015). Such short-time effects may be of great importance within high-performance settings when the goal is to quickly achieve a specific outcome. From a talent development viewpoint, however, developing players' skills systematically would benefit from knowledge on learning effects, thus, requiring the inclusion of retention tests within intervention designs. Additionally, knowledge about methods resulting in positive transfer to other skills but also from decontextualized to game-realistic settings would provide valuable information on how to effectively prepare players for the dynamic nature of the game.

A further identified concern relates to the scarce description of interventions which limits the potential to replicate the reviewed studies. Besides that, little consideration was dedicated to the intervention adherence and fidelity. Systematic assessments based on specific and outlined criteria of observation provide transparent insights on the intervention delivery (e.g., Práxedes et al., 2019). Especially within the highly dynamic and partly unpredictable pitch-based work, systematic assessments would add valuable information on the interventions' protocol adherence.

Outcome Variables and Statistical Analysis

The multitude of dependent variables illustrates the variety of relevant outcomes even within the perceptual-motor and perceptual-cognitive skill domains. Yet, multiple ways for measuring the same skills underline that there is no consensus regarding standard assessment tools (Williams et al., 2020). Additionally, instruments lacking a scientifically sound investigation of reliability and validity were found. Those results need to be interpreted with caution. Besides outcome-related skill tests, also an increasing number of in-game assessments were applied. These provide higher ecological validity and the opportunity to assess the functional application of practiced skills (for a similar discussion see Koopmann et al., 2020).

However, many interfering factors (e.g., performance of other players) need to be controlled. Consequently, combining skill tests and in-game assessments is recommended.

A further prevalent issue was the low statistical power due to small sample sizes. Unsurprisingly given this result—and in line with similar investigations in sports science research (Abt et al., 2020)—only five studies reported a priori sample size estimations. Further, correlations among repeated measures in individual studies were unknown and may have resulted in less precise *post-hoc* power calculations. Besides inferential statistics, two studies used magnitude-based inferences, however, it is intensively discussed within sports science whether the use of such parameters is adequate as they are often used to justify small sample sizes (Lohse et al., 2020). Additionally, insufficient reports or interpretations of statistical results, missing interaction effects, or unknown group differences challenged the recalculation and interpretation of effect sizes.

Overall, these limitations reinforced the decision to refrain from a meta-analysis and need to be recognized when interpreting and comparing the effectiveness of interventions. Due to the diverse approaches, many studies must be considered in the light of individual characteristics.

Effectiveness of DL, TGFU, and NLP Interventions

A fundamental question arising from theoretical camps is as to whether practice should aim to improve ideal "textbook" techniques or allow exploration for individual solutions. Seven studies on DL dealt with this question, but large methodological differences and a low statistical power must be considered.

Only a few significant effects were found that confirm the superiority of DL compared to TL methods. Nevertheless, no study reported significantly greater effectiveness of TL methods, permitting the conclusion that DL seems to be at least a viable alternative for practicing technical soccer skills. Supporting this notion, comparisons to non-active CGs provide evidence that DL could generally improve performance (e.g., Ozuak and Çaglayan, 2019). Yet, besides two exceptions, the performance was assessed within skill tests. Thus, investigations that DL supports "more effective and more stable movement patterns" (Schöllhorn et al., 2012, p. 102) within match-play have been widely neglected so far. Further, the greater effectiveness of DL in the retention phase compared to the acquisition phase as found in a meta-analysis by Tassignon et al. (2021) could not be proofed due to the absence of retention tests in most studies.

The two studies on game-based DL support its potential to promote divergent tactical behavior in early- to mid-adolescent regional level players (e.g., Santos et al., 2018). Although generalizable conclusions seem premature due to only two game-based studies on divergent tactical outcomes, the results provide support for a developmental framework on promoting creativity in team sports, recommending DL as one appropriate method during adolescence (Santos et al., 2016).

In contrast to DL, studies on TGFU and NLP consistently aimed at promoting technical and convergent tactical skills (i.e., decision-making). Generally, positive effects regarding the promotion of perceptual-motor and perceptual-cognitive skills indicate the potential of both approaches although only two controlled designs were found. Besides, many studies rather provide evidence on the general effectiveness as targeted practice objectives in IGs (technical and tactical content) and CGs (primarily technical content) seem hardly comparable.

The predominant use of SSGs with numerical superiority led to greater effects in passing variables (e.g., Práxedes et al., 2018a). Consequently, if improvements in dribbling should be targeted, other strategies to simplify game demands are required. As a general result, more significant effects in perceptual-cognitive compared to perceptual-motor variables were found, probably due to the predominant focus on technical skills in CGs. Further, intervention periods longer than eight sessions as used by Roberts et al. (2020) or greater consideration of the technical elements (e.g., applied technical practice) may achieve greater effectiveness in the perceptual-motor domain.

Effectiveness of Interventions Focusing on Specific Aspects of Practice or Coaching

Providing a clear image of the effectiveness of studies on specific aspects to practice and coaching is challenged as diverse topics within skill acquisition research, practice methods, and technical outcomes were found. Further, most technical outcomes were only investigated through skills tests limiting the inferences which can be drawn for match-play performances. Nevertheless, most studies support the effectiveness of deliberate technical practice although specific study objectives and particularities of applied methods often require individual analyses. Specifically, positive results were reported after technically focused drill-based interventions to promote the technical non-dominant leg performance. Thus, interventions that primarily include TL methods—often applied as supplemental to regular team practice—were found to achieve improvements. Again, none of these studies assessed its impact on match-play performance. Only two studies provide support that drill-based practices over several months can positively impact match-play behavior in terms of a higher utilization rate of the non-dominant leg (Guilherme et al., 2015a,b). In summary, the present research on specific aspects provides first insights on the potential of different practice and coaching methods, but evidence on whether such practices can improve match-play performance is rare.

Limitations of This Systematic Review

The limitations of the present review mainly relate to three characteristics. *First,* due to large heterogeneity and methodological weaknesses across studies, pooling effect sizes within a meta-analysis to increase the statistical power and precision of effects was not possible. Besides the limited number of controlled designs on comparable approaches, not all effect sizes could be recalculated due to missing data, as well as unknown interaction effects or group differences. Consequently, inferences on the effectiveness of interventions were limited, they could not be statistically investigated regarding potential moderators (e.g., the intervention duration) and, thus, must be often interpreted in the light of individual study characteristics. Along with this, the extent of potential publication biases could not be statistically assessed. *Second*, strict inclusion criteria were applied to ensure the highest quality of individual studies (e.g., peer-reviewed research). Nevertheless, relevant studies published within different outlets (e.g., book chapters) may have been omitted as a consequence. *Third*, improvements in players' perceptual-motor and perceptual-cognitive skills were chosen from a wide range of potentially relevant outcomes (Nichol et al., 2019). Thus, skill acquisition needs to be considered at the interface of various interrelating elements, such as motivational or physiological attributes.

Future Perspectives

The growing number of studies over the past years elucidated the increasing interest and relevance of the topic. To encourage and improve further work, directions and recommendations for future studies are outlined relating to three main features.

First, *higher standards of intervention research* should be applied, especially in terms of sufficiently powered and controlled designs. Although guidelines for intervention research from health science or medicine may need to be translated and adapted for sports coaching research (e.g., O'Cathain et al., 2019), they can be valuable benchmarks for future work. Further, scientifically grounded and clearly outlined hypotheses are required to better understand what interventions aim to achieve. Pre-registrations could improve the current practice by outlining the study design, hypotheses, statistical analyses, and a priori sample size estimation.

Second, the specific practice objectives of different practice and coaching methods should be critically juxtaposed to conduct *theory-driven intervention research on the relative effectiveness* of approaches (for an example see Gray, 2020). Here, the additional use of non-active or usual care CGs would allow interpreting improvements in different practice groups. The application of instruments with high specificity is recommended to draw sound conclusions on the respective intervention objectives. These can be both outcome-related skill tests, but also representative in-game assessments if potential confounders could be controlled. Additionally to hypothesis testing based on group means, looking at individual development curves would allow specific implications on how different methods impact acquisition and learning in the light of personal characteristics (Anderson et al., 2021).

Third, systematic *monitoring of practice and coaching* would help to better understand and compare the implementation of different approaches. This requires empirically grounded metrics to quantify practice (e.g., variability) and coaching (e.g., instructions). Although proper metrics are scarce, systematic observation instruments can provide valuable data (e.g., Cushion et al., 2012b). Potentially relevant variables may also be adapted from periodization frameworks on skill acquisition (Farrow and Robertson, 2017; Otte et al., 2019). Collaborations with coaches who transfer methodological principles to their "real-world" coaching contexts could show how differently grounded approaches can be applied in different settings. This could specifically profit from mixed-method designs focusing on both the players' outcomes, but also coaches' intentions, expectations, and experiences when applying different methodologies.

Practical Implications

The present findings underline the need for coaches to make numerous considerations before deciding for or against a specific practice and coaching methodology. These may include, for example, coaches' reflections on which competencies they aim to improve in their players (i.e., the practice objectives) as well as the situative circumstances in which practice is conducted (e.g., age groups or sport facilities). Within coaches' daily work, but beyond the scope of the present review, these considerations cannot be limited to perceptual-motor and perceptual-cognitive skills, but need to go further (see, for example, Alves et al., 2017 for reasons on the use of SSGs in soccer practice).

Regarding the promotion of outcomes addressing *technical skills*, the available results support that both decomposed, repetition-based approaches as well as self-organziation/variability-based approaches implemented within drills or games can lead to improvements depending on how performance is operationalized. These findings challenge the traditional idea that players must learn the "fundamentals" first (e.g., ball handling) before they can be put into the game context (Newell, 2020). Given the other benefits of self-organization/game-based practice activities (e.g., more opportunities for decision-making), this suggests that, at very least, coaches should reduce the amount of decomposed, isolated drills in practice. Here, the key challenge is to find the most supportive integration and periodization of such practices, as well as the optimal degree of self-exploration and variability by considering individuals' requirements and needs.

Regarding *convergent tactical skills* (i.e., decision-making), the present results allow the cautious conclusion that those approaches which provide players a greater opportunity to self-explore tactical solutions within game-realistic settings provide a better foundation to facilitate convergent tactical thinking. Knowledge of how and to what degree this process can be most effectively guided through implicit or explicit coaching strategies is still scarce as comparisons of specific strategies are lacking. In terms of players' *divergent tactical behavior*, it seems worthwhile to confront players with highly dynamic and unpredictable match-play situations that encourage flexible adaptions to game demands. Nevertheless, specific recommendations on the most conducive degree of variability and unpredictability cannot be made based on the present knowledge.

CONCLUSION

The small number of studies investigating similar approaches, heterogeneity across studies and dependent variables, as well as methodological weaknesses, limit the generalizability of results. Although it was possible to outline the potential of different practice and coaching methods regarding a variety of outcomes, most effects need to be critically interpreted in the light of individual study characteristics and weaknesses. Thus, based on the current body of knowledge, drawing scientifically sound conclusions on the effectiveness or even superiority of specific approaches would be premature. Rather, the present review aims to encourage further theory-driven and high-quality studies to extend the growing but still limited body of research conducted in applied experimental contexts. Furthermore, the findings must be systematically enriched by coaches' experiential knowledge. This will contribute to a conscious and evidence-based use of the coaches' methodological "toolbox" for effectively enhancing player learning and performance.

DATA AVAILABILITY STATEMENT

Further data, as well as the PRISMA checklist, are provided in **Supplementary Materials I-V**. Datasets of the systematic search and the quantitative synthesis can be accessed in the OSF project of this publication (https://osf.io/85tjg/).

AUTHOR CONTRIBUTIONS

FB, RG, SW, and OH: conceptualization, review, and editing original draft. FB: methodology, investigation and formal analysis, and visualization and writing original draft. OH: project administration and supervision, and funding acquisition. All authors contributed to the article and approved the submitted version.

FUNDING

This study was part of the research project "Scientific Support of the DFB's Talent Promotion Program", which was granted by the German Football Association (Deutscher Fußball-Bund, DFB). The funder was not involved in the study design, collection, analysis, interpretation of data, the writing of this article or the decision to submit it for publication. We also acknowledge support by Open Access Publishing Fund of the Eberhard Karls University Tübingen. This funding supported the payment of the publication fee.

ACKNOWLEDGMENTS

We would like to thank the staff of the DFB's Department for Talent Development for productive discussions in several meetings. We would also like to thank all authors who shared their original data for performing the quantitative synthesis, as well as Lena Kober for her assistance in conducting the systematic search and article screening.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.772201/full#supplementary-material

REFERENCES

Abad Robles, M. T., Collado-Mateo, D., Fernández-Espínola, C., Castillo Viera, E., and Giménet Fuentes-Guerra, F. J. (2020). Effects of teaching games on decision making and skill execution: a systematic review and meta-analysis. *Int. J. Environ. Res. Public Health* 17, 1–13. doi: 10.3390/ijerph17020505

Abt, G., Boreham, C., Davison, G., Jackson, R., Nevill, A., Wallace, E., et al. (2020). Power, precision, and sample size estimation in sport and exercise science research. *J. Sports Sci.* 38, 1933–1935. doi: 10.1080/02640414.2020.1776002

Alves, G., Clemente, F., Sousa, P., Pinheiro, V., and Santos, F. (2017). How and why do soccer coaches use small-sided games in the training process? *Hum. Mov.* 18, 117–124. doi: 10.5114/hm.2017.73624

Anderson, D. I., Lohse, K. R., Lopes, T. C. V., and Williams, A. M. (2021). Individual differences in motor skill learning: Past, present and future. *Hum. Mov. Sci.* 78:102818. doi: 10.1016/j.humov.2021.102818

Anderson, D. I., and Sidaway, B. (1994). Coordination changes associated with practice of a soccer kick. *Res. Q. Exerc. Sport* 65, 93–99. doi: 10.1080/02701367.1994.10607603

Anson, J., Elliott, D., and Davids, K. (2005). Information processing and constraints-based views of skill acquisition: divergent or complementary? *Motor Control* 9, 217–241. doi: 10.1123/mcj.9.3.217

*Arslan, E., Orer, G. E., and Clemente, F. M. (2020). Running-based high-intensity interval training vs. small-sided game training programs: effects on the physical performance, psychophysiological responses and technical skills in young soccer players. *Biol. Sport* 37, 165–173. doi: 10.5114/biolsport.2020.94237

*Barquero-Ruiz, C., Morales-Belando, M. T., and Arias-Estero, J. L. (2020). A teaching games for understanding program to deal with reasons for dropout in under-11 football. *Res. Q. Exerc. Sport* 1–12. doi: 10.1080/02701367.2020.1759767

*Bekris, E., Gioldasis, A., Mylonis, E., Gissis, I., Sarakinos, A., Komsis, S., et al. (2012). The effects of practicing with a size-2 ball on the technical skills of young soccer players of a different level. *J. Phys. Educ. Sport* 12, 514–520.

Bergmann, F., Gray, R., Wachsmuth, S., and Höner, O. (2020). The influence of practice design and coaching behavior on skill acquisition in soccer: A systematic review protocol (PRISMA-P). doi: 10.17605/OSF.IO/NUYZP

Bernstein, N. A. (1967). *The Co-ordination and Regulation of Movements*. Oxford: Pergamon Press.

*Boraczyński, M. T., Sozański, H. A., and Boraczyński, T. W. (2019). Effects of a 12-month complex proprioceptive-coordinative training program on soccer performance in prepubertal boys aged 10-11 years. *J. Strength Condition. Res.* 33, 1380–1393. doi: 10.1519/JSC.0000000000001878

*Bozkurt, S. (2018). The effects of differential learning and traditional learning trainings on technical development of football players. *J. Educ. Training Stud.* 6, 25–29. doi: 10.11114/jets.v6i4a.3229

Bujalance-Moreno, P., Latorre Román, P., and Pinillos, F. (2018). A systematic review on small-sided games in football players: acute and chronic adaptations. *J. Sports Sci.* 37, 921–941. doi: 10.1080/02640414.2018.1535821

Bunker, D., and Thorpe, R. (1982). A model for teaching of games in secondary school. *Bull. Phys. Educ.* 18, 5–8.

Chow, J. Y., Davids, K., Hristovski, R., Araújo, D., and Passos, P. (2011). Nonlinear pedagogy: learning design for self-organizing neurobiological systems. *New Ideas Psychol.* 29, 189–200. doi: 10.1016/j.newideapsych.2010.10.001

Cohen, J. (1988). *Statistical Power Analysis of the Behavioral Sciences*. New York, NY: Routledge.

Cope, E., and Cushion, C. (2020). *A Move Towards Reconceptualising Direct Instruction in Sport Coaching Pedagogy. Impact*. Available online at: https://impact.chartered.college/article/a-move-towards-reconceptualising-direct-instruction-sport-coaching-pedagogy/ (accessed September 6, 2021).

Côté, J., and Gilbert, W. (2009). An integrative definition of coaching effectiveness and expertise. *Int. J. Sports Sci. Coach.* 4, 307–323. doi: 10.1260/174795409789623892

*Coutinho, D., Santos, S., Gonçalves, B., Travassos, B., Wong, D. P., Schöllhorn, W., et al. (2018). The effects of an enrichment training program for youth football attackers. *PLoS ONE* 13:e0199008. doi: 10.1371/journal.pone.0199008

Cushion, C. J., Ford, P., and Williams, A. M. (2012a). Coach behaviours and practice structures in youth soccer: implications for talent development. *J. Sports Sci.* 30, 1631–1641. doi: 10.1080/02640414.2012.721930

Cushion, C. J., Harvey, S., Muir, B., and Nelson, L. (2012b). Developing the Coach Analysis and Intervention System (CAIS): Establishing validity and reliability of a computerised systematic observation instrument. *J. Sports Sci.* 30, 201–216. doi: 10.1080/02640414.2011.635310

Davies, T. B., Kuang, K., Orr, R., Halaki, M., and Hackett, D. (2017). Effect of movement velocity during resistance training on dynamic muscular strength: a systematic review and meta-analysis. *Sports Med.* 47, 1603–1617. doi: 10.1007/s40279-017-0676-4

Deeks, J. J., Higgins, J. P. T., and Altman, D. G. (2021). "Analysing data and undertaking meta-analyses," in *Cochrane Handbook for Systematic Reviews of Interventions*, eds J. P. T. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. J. Page, and V. A. Welch (Vol. 6.2, updated february 2021). Cochrane. Available online at: www.training.cochrane.org/handbook (accessed September 6, 2021).

Demetriou, Y., and Höner, O. (2012). Physical activity interventions in the school setting: a systematic review. *Psychol. Sport Exerc.* 13, 186–196. doi: 10.1016/j.psychsport.2011.11.006

Downs, S. H., and Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J. Epidemiol. Commun. Health* 52, 377–384. doi: 10.1136/jech.52.6.377

Farrow, D. (2021). "Technical and tactical development of athletes," in *Sport Coaches' Handbook*, eds D. Gould and C. Mallett (Champaign: Human Kinetics), 181–202.

Farrow, D., and Robertson, S. (2017). Development of a skill acquisition periodisation framework for high-performance sport. *Sports Med.* 47, 1043–1054. doi: 10.1007/s40279-016-0646-2

Fitts, P. M., and Posner, M. I. (1979). *Human Performance*. Belmont, CA: Brooks/Cole.

Ford, P., Yates, I., and Williams, A. M. (2010). An analysis of practice activities and instructional behaviours used by youth soccer coaches during practice: exploring the link between science and application. *J. Sports Sci.* 28, 483–495. doi: 10.1080/02640410903582750

Forsman, H., Blomqvist, M., Davids, K., Konttinen, N., and Liukkonen, J. (2016). The role of sport-specific play and practice during childhood in the development of adolescent Finnish team sport athletes. *Int. J. Sports Sci. Coach.* 11, 69–77. doi: 10.1177/1747954115624816

García López, L. M., Víllora, S. G., del Campo, D. G. D., and Olivares, J. S. (2013). Development and validation of the Game Performance Evaluation Tool (GPET) in soccer. *Revista Euroamericana de Ciencias del Deporte* 2, 89–99.

*Gaspar, A., Santos, S., Coutinho, D., Gonçalves, B., Sampaio, J., and Leite, N. (2019). Acute effects of differential learning on football kicking performance and in countermovement jump. *PLoS ONE* 14:e0224280. doi: 10.1371/journal.pone.0224280

Gibson, J. J. (1979). *The Ecological Approach to Visual Perception*. Boston, MA: Houghton Mifflin.

Gould, D., and Mallett, C. (2021). "The coaching role," in Sport Coaches' Handbook, eds D. Gould and C. Mallett (Champaign: Human Kinetics), 1–12.

Gray, R. (2020). Comparing the constraints led approach, differential learning and prescriptive instruction for training opposite-field hitting in baseball. *Psychol. Sport Exerc.* 51:101797. doi: 10.1016/j.psychsport.2020.101797

Grgic, J., Schoenfeld, B. J., Davies, T. B., Lazinica, B., Krieger, J. W., and Pedisic, Z. (2018). Effect of resistance training frequency on gains in muscular strength: a systematic review and meta-analysis. *Sports Med.* 48, 1207–1220. doi: 10.1007/s40279-018-0872-x

*Guilherme, J., Garganta, J., Graça, A., and Seabra, A. (2015a). Effects of technical training in functional asymmetry of lower limbs in young soccer players. *Braz. J. Kineanthropometry Human Perform.* 17, 125–135.

*Guilherme, J., Garganta, J., Graça, A., and Seabra, A. (2015b). Influence of non-preferred foot technical training in reducing lower limbs functional asymmetry among young football players. *J. Sports Sci.* 33, 1790–1798. doi: 10.1080/02640414.2015.1012100

Guilherme, J., Garganta, J., Seabra, A., and Amândio, G. (2012). Validação de um sistema de avaliação da assimetria funcional dos membros inferiores em Futebol (SAFALL-FOOT). *Revista Portuguesa de Ciências do Desporto* 12, 77–97. doi: 10.5628/rpcd.12.03.77

Güllich, A., Macnamara, B. N., and Hambrick, D. Z. (2021). What makes a Champion? Early multidisciplinary practice, not early specialization predicts world-class performance. *Perspect. Psychol. Sci.* doi: 10.1177/1745691620974772

*Haaland, E., and Hoff, J. (2003). Non-dominant leg training improves the bilateral motor performance of soccer players. *Scand. J. Med. Sci. Sports* 13, 179–184. doi: 10.1034/j.1600-0838.2003.00296.x

Hallgren, K. A. (2012). Computing Inter-rater reliability for observational data: an overview and tutorial. *Tutorials Quant. Methods Psychol.* 8, 23–34. doi: 10.20982/tqmp.08.1.p023

Harari, M. B., Parola, H. R., Hartwell, C. J., and Riegelman, A. (2020). Literature searches in systematic reviews and meta-analyses: a review, evaluation, and recommendations. *J. Vocat. Behav.* 118:103377. doi: 10.1016/j.jvb.2020.103377

*Harvey, S., Cushion, C. J., Wegis, H. M., and Massa-Gonzalez, A. N. (2010). Teaching games for understanding in American high-school soccer: a quantitative data analysis using the game performance assessment instrument. *Phys. Educ. Sport Pedagogy* 15, 29–54. doi: 10.1080/17408980902729354

Harvey, S., Pill, S., and Almond, L. (2018). Old wine in new bottles: a response to claims that teaching games for understanding was not developed as a theoretically based pedagogical framework. *Phys. Educ. Sport Pedagogy* 23, 166–180. doi: 10.1080/17408989.2017.1359526

Hendry, D. T., Ford, P., Williams, A. M., and Hodges, N. J. (2015). "Five evidence-based principles of effective practice and instruction," in *Routledge Handbook of Sport Expertise*, eds J. Baker and D. Farrow (New York, NY: Routledge), 414–429. doi: 10.4324/9781315776675-36

Hendry, D. T., and Hodges, N. J. (2019). Pathways to expert performance in soccer. *J. Expert.* 2, 1–13.

Hodges, N. J., Hayes, S., Horn, R. R., and Williams, A. M. (2005). Changes in coordination, control and outcome as a result of extended practice on a novel motor skill. *Ergonomics* 48, 1672–1685. doi: 10.1080/00140130500101312

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., et al. (2014). Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ* 348:g1687. doi: 10.1136/bmj.g1687

*Holt, J. E., Kinchin, G., and Clarke, G. (2012). Effects of peer-assessed feedback, goal setting and a group contingency on performance and learning by 10–12-year-old academy soccer players. *Phys. Educ. Sport Pedagogy* 17, 231–250. doi: 10.1080/17408989.2012.690568

*Hossner, E.-J., Käch, B., and Enz, J. (2016). On the optimal degree of fluctuations in practice for motor learning. *Hum. Mov. Sci.* 47, 231–239. doi: 10.1016/j.humov.2015.06.007

Koopmann, T., Faber, I., Baker, J., and Schorer, J. (2020). Assessing technical skills in talented youth athletes: a systematic review. *Sports Med.* 50, 1593–1611. doi: 10.1007/s40279-020-01299-4

*Kösal, M., Gül, G. K., Doganay, M., and Álvarez-García, C. (2020). Effects of coordination training on the technical development in 10-13 years old football players. *J. Sports Med. Phys. Fitness* 61, 497–504. doi: 10.23736/S0022-4707.20.11270-2

Lohse, K. R., Sainani, K. L., Taylor, J. A., Butson, M. L., Knight, E. J., and Vickers, A. J. (2020). Systematic review of the use of "magnitude-based inference" in sports science and medicine. *PLoS ONE* 15:e0235318. doi: 10.1371/journal.pone.0235318

Magill, R. A., and Anderson, D. I. (2020). *Motor Learning and Control: Concepts and Applications. 12th Edn*. New York, NY: McGraw-Hill.

*Miranda, R. E. E. P. C., Antunes, H. K. M., Pauli, J. R., Puggina, E. F., and da Silva, A. S. R. (2013). Effects of 10-week soccer training program on anthropometric, psychological, technical skills and specific performance parameters in youth soccer players. *Sci. Sports* 28, 81–87. doi: 10.1016/j.scispo.2012.02.005

Moher, D., Liberati, A., Tetzlaff, J., and Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 339:b2535. doi: 10.1136/bmj.b2535

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., et al. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst. Rev.* 4:1. doi: 10.1186/2046-4053-4-1

*Montesano, P., and Mazzeo, F. (2019). Improvement in soccer learning and methodology for young athletes. *J. Phys. Educ. Sport* 19, 795–801.

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. *Organ. Res. Methods* 11, 364–386. doi: 10.1177/1094428106291059

Newell, K. M. (1986). "Constraints on the development of coordination," in *Motor Development in Children: Aspects of Coordination and control*, eds M. G. Wade and H. T. A. Whiting (Dordrecht: Mathinus Nijhoff), 341–361. doi: 10.1007/978-94-009-4460-2_19

Newell, K. M. (2020). What are fundamental motor skills and what is fundamental about them? *J. Motor Learn. Dev.* 8, 280–314. doi: 10.1123/jmld.2020-0013

Nichol, A. J., Hall, E. T., Vickery, W., and Hayes, P. R. (2019). Examining the relationships between coaching practice and athlete outcomes: a systematic review and critical realist critique. *Int. Sport Coach. J.* 6, 13–29. doi: 10.1123/iscj.2017-0105

O'Cathain, A., Croot, L., Duncan, E., Rousseau, N., Sworn, K., Turner, K. M., et al. (2019). Guidance on how to develop complex interventions to improve health and healthcare. *BMJ Open* 9:e029954. doi: 10.1136/bmjopen-2019-029954

O'Connor, D., Larkin, P., Robertson, S., and Goodyear, P. (2021). The art of the question: the structure of questions posed by youth soccer coaches during training. *Phys. Educ. Sport Pedagogy*. doi: 10.1080/17408989.2021.1877270

O'Connor, D., Larkin, P., and Williams, A. M. (2017). What learning environments help improve decision-making? *Phys. Educ. Sport Pedagogy* 22, 647–660. doi: 10.1080/17408989.2017.1294678

O'Connor, D., Larkin, P., and Williams, A. M. (2018). Observations of youth football training: how do coaches structure training sessions for player development? *J. Sports Sci.* 36, 39–47. doi: 10.1080/02640414.2016.1277034

Oslin, J. L., Mitchell, S. A., and Griffin, L. L. (1998). The Game Performance Assessment Instrument (GPAI): development and preliminary validation. *Hum Kinetics J.* 17, 231–243. doi: 10.1123/jtpe.17.2.231

Otte, F., Davids, K., Millar, S.-K., and Klatt, S. (2020). When and how to provide feedback and instructions to athletes?—How sport psychology and pedagogy insights can improve coaching interventions to enhance self-regulation in training. *Front. Psychol.* 11:1444. doi: 10.3389/fpsyg.2020.01444

Otte, F. W., Millar, S.-K., and Klatt, S. (2019). Skill training periodization in "Specialist" sports coaching—an introduction of the "PoST" framework for skill development. *Front. Sports Act. Living* 1:61. doi: 10.3389/fspor.2019.00061

*Ozuak, A., and Çaglayan, A. (2019). Differential learning as an important factor in training of football technical skills. *J. Educ. Train. Stud.* 7, 68–76. doi: 10.11114/jets.v7i6.4135

Partington, M., and Cushion, C. (2013). An investigation of the practice activities and coaching behaviors of professional top-level youth soccer coaches. *Scand. J. Med. Sci. Sports* 23, 374–382. doi: 10.1111/j.1600-0838.2011.01383.x

Partington, M., Cushion, C. J., and Harvey, S. (2014). An investigation of the effect of athletes' age on the coaching behaviours of professional top-level youth soccer coaches. *J. Sports Sci.* 32, 403–414. doi: 10.1080/02640414.2013.835063

*Práxedes Pizarro, A., Domínguez, A. M., Serrano, J. S., García-González, L., and del Villar Álvarez, F. (2017). The effect of a comprehensive teaching program on dribbling and passing decision-making and execution of skills of young footballers. *Kinesiology* 49, 74–83. doi: 10.26582/k.49.1.6

*Práxedes, A., Del Villar Álvarez, F., Moreno, A., Gil-Arias, A., and Davids, K. (2019). Effects of a nonlinear pedagogy intervention programme on the emergent tactical behaviours of youth footballers. *Phys. Educ. Sport Pedagogy* 24, 332–343. doi: 10.1080/17408989.2019.1580689

*Práxedes, A., Del Villar, F., Pizarro, D., and Moreno, A. (2018a). The impact of nonlinear pedagogy on decision-making and execution in youth soccer players according to game actions. *J. Hum. Kinet.* 62, 185–198. doi: 10.1515/hukin-2017-0169

*Práxedes, A., Moreno, A., Gil-Arias, A., Claver, F., and Del Villar, F. (2018b). The effect of small-sided games with different levels of opposition on the tactical behaviour of young footballers with different levels of sport expertise. *PLoS ONE* 13:e0190157. doi: 10.1371/journal.pone.0190157

*Práxedes, A., Moreno, A., Sevil, J., García-González, L., and Del Villar, F. (2016). A preliminary study of the effects of a comprehensive teaching program, based on questioning, to improve tactical actions in young footballers. *Percept. Motor Skills* 122, 742–756. doi: 10.1177/0031512516649716

Price, A., Collins, D., Stoszkowski, J., and Pill, S. (2019). Coaching games: comparisons and contrasts. *Int. Sport Coach. J.* 6, 126–131. doi: 10.1123/iscj.2018-0015

Proteau, L. (1992). "On the specifity of learning and the role of visual information for movement and control," in *Vision and motor control*, eds L. Proteau and D. Elliott (Amsterdam: Elsevier Science), 67–102. doi: 10.1016/S0166-4115(08)62011-7

Raabe, J., Schmidt, K., Carl, J., and Höner, O. (2019). The effectiveness of autonomy support interventions with physical education teachers and youth sport coaches: a systematic review. *J. Sport Exercise Psychol.* 41, 345–355. doi: 10.1123/jsep.2019-0026

*Raastad, O., Aune, T. K., and van den Tillaar, R. (2016). Effect of practicing soccer juggling with different sized balls upon performance, retention, and transfer to ball reception. *Motor Control* 20, 337–349. doi: 10.1123/mc.2015-0026

*Radziminski, L., Rompa, P., Barnat, W., Dargiewicz, R., and Jastrzebski, Z. (2013). A comparison of the physiological and technical effects of high-intensity running and small-sided games in young soccer players. *Int. J. Sports Sci. Coach.* 8, 455–466. doi: 10.1260/1747-9541.8.3.455

Ramos, A., Coutinho, P., Leitão, J. C., Cortinhas, A., Davids, K., and Mesquita, I. (2020). The constraint-led approach to enhancing team synergies in sport - What do we currently know and how can we move forward? A systematic review and meta-analyses. *Psychol. Sport Exercise* 50:101754. doi: 10.1016/j.psychsport.2020.101754

Renshaw, I., Araújo, D., Button, C., Chow, J. Y., Davids, K., and Moy, B. (2016). Why the Constraints-Led Approach is not Teaching Games for Understanding: a clarification. *Phys. Educ. Sport Pedagogy* 21, 459–480. doi: 10.1080/17408989.2015.1095870

*Roberts, S. J., Rudd, J. R., and Reeves, M. J. (2020). Efficacy of using non-linear pedagogy to support attacking players' individual learning objectives in elite-youth football: a randomised cross-over trial. *J. Sports Sci.* 38, 1454–1464. doi: 10.1080/02640414.2019.1609894

Roca, A., and Ford, P. R. (2020). Decision-making practice during coaching sessions in elite youth football across European countries. *Sci. Med. Football* 4, 263–268. doi: 10.1080/24733938.2020.1755051

*Santos, S., Coutinho, D., Goncalves, B., Schollhorn, W., Sampaio, J., and Leite, N. (2018). Differential learning as a key training approach to improve creative and tactical behavior in soccer. *Res. Q. Exerc. Sport* 89, 11–24. doi: 10.1080/02701367.2017.1412063

Santos, S., Jiménez, S., Sampaio, J., and Leite, N. (2017). Effects of the Skills4Genius sports-based training program in creative behavior. *PLoS ONE* 12:e0172520. doi: 10.1371/journal.pone.0172520

Santos, S., Memmert, D., Sampaio, J., and Leite, N. (2016). The spawns of creative behavior in team sports: a creativity developmental framework. *Front. Psychol.* 7:1282. doi: 10.3389/fpsyg.2016.01282

Schmidt, R. A. (1975). A schema theory of discrete motor skill learning. *Psychol. Rev.* 82, 225–260. doi: 10.1037/h0076770

Schmidt, R. A., Lee, T., Winstein, C., Wulf, G., and Zelaznik, H. (2019). *Motor Control and Learning. A Behavioral Emphasis. 6th Edn*. Champaign: Human Kinetics.

Schöllhorn, W. (1999). Individualität - ein vernachlässigter Parameter? *[Individualy - a neglected parameter?]. Leistungssport* 29, 5–12.

*Schöllhorn, W. I., Beckmann, H., Michelbrink, M., Sechelmann, M., Trockel, M., and Davids, K. (2006). Does noise provide a basis for the unification of motor learning theories? *Int. J. Sport Psychol*. 37, 186–206.

*Schöllhorn, W. I., Hegen, P., and Davids, K. (2012). The nonlinear nature of learning - a differential learning approach. *Open Sports Sci. J.* 5, 100–112. doi: 10.2174/1875399X01205010100

*Schwab, S., Rein, R., and Memmert, D. (2019). "Kick it like Ronaldo": a crosssectional study of focus of attention effects during learning of a soccer knuckle ball free kick technique. *German J. Exerc. Sport Res.* 49, 91–96. doi: 10.1007/s12662-018-0558-4

Sieghartsleitner, R., Zuber, C., Zibung, M., and Conzelmann, A. (2018). "The Early Specialised Bird Catches the Worm!" – a specialised sampling model in the development of football talents. *Front. Psychol.* 9:188. doi: 10.3389/fpsyg.2018.00188

*Sierra-Ríos, J. V., Clemente, F. M., Rey, E., and González-Víllora, S. (2020). Effects of 6 weeks direct instruction and teaching games for understanding programs on physical activity and tactical behaviour in U-12 soccer players. *Int. J. Environ. Res. Public Health* 17:5008. doi: 10.3390/ijerph17145008

Silva, A., Ramirez-Campillo, R., Sarmento, H., Afonso, J., and Clemente, F. M. (2021). Effects of training programs on decision-making in youth team sports players: a systematic review and meta-analysis. *Front. Psychol.* 12:663867. doi: 10.3389/fpsyg.2021.663867

Silva, A. F., Conte, D., and Clemente, F. M. (2020). Decision-making in youth team-sports players: a systematic review. *Int. J. Environ. Res. Public Health* 17, 1–23. doi: 10.3390/ijerph17113803

Smelt, A., Blom, J., Gussekloo, J., and Assendelft, W. (2010). How usual is usual care in pragmatic intervention studies in primary care? An overview of recent trials. *Br. J. General Pract.* 60, e305–318. doi: 10.3399/bjgp10X514819

Soderstrom, N. C., and Bjork, R. A. (2015). Learning versus performance:an integrative review. *Perspect. Psychol. Sci.* 10, 176–199. doi: 10.1177/1745691615569000

Spittle, M. (2021). *Motor Learning and Skill Acquisition. Applications for Physical Education and Sport. 2nd Edn*. London: Red Globe Press.

Stratton, G., Reilly, T., Williams, A. M., and Richardson, D. (2004). *Youth Soccer. From Science to Performance*. London; New York, NY: Routledge.

Tassignon, B., Verschueren, J., Baeyens, J.-P., Benjaminse, A., Gokeler, A., Serrien, B., et al. (2021). An exploratory meta-analytic review on the empirical evidence of differential learning as an enhanced motor learning method. *Front. Psychol.* 12:1186. doi: 10.3389/fpsyg.2021.533033

*Teixeira, L. A., Silva, V. M., and Carvalho, M. A. (2003). Reduction of lateral asymmetries in dribbling: the role of bilateral practice. *Laterality* 8, 53–65. doi: 10.1080/713754469

Tod, D. (2019). *Conducting Systematic Reviews in Sport, Exercise, and Physical Acitivity*. Cham: Palgrave Macmillan. doi: 10.1007/978-3-030-12263-8

Uehara, L., Button, C., Araujo, D., Renshaw, I., Davids, K., and Falcous, M. (2018). The role of informal, unstructured practice in developing football expertise: the case of Brazilian pelada. *J. Expert.* 1, 162–180.

Vater, C., Gray, R., and Holcombe, A. O. (2021). A critical systematic review of the neurotracker perceptual-cognitive training tool. *Psychon. Bull. Rev*. 28, 1458–1483. doi: 10.3758/s13423-021-01892-2

*Weigelt, C., Williams, A. M., Wingrove, T., and Scott, M. A. (2000). Transfer and motor skill learning in association football. *Ergonomics* 43, 1698–1707. doi: 10.1080/001401300750004104

Whitall, J., Bardid, F., Getchell, N., Melissa, N., Pangelinan, N., Robinson, L. E., et al. (2020a). Motor development research: II. the first two decades of the 21st century shaping our future. *J. Motor Learn. Dev.* 8, 363–390. doi: 10.1123/jmld.2020-0007

Whitall, J., Schott, N., Robinson, L. E., Bardid, F., and Clark, J. E. (2020b). Motor development research: I. the lessons of history revisited (the 18th to the 20th Century). *J. Motor Learn. Dev.* 8, 345–362. doi: 10.1123/jmld.2019-0025

Williams, A. M., Ford, P. R., and Drust, B. (2020). Talent identification and development in soccer since the millennium. *J. Sports Sci.* 38, 1199–1210. doi: 10.1080/02640414.2020.1766647

Williams, A. M., and Hodges, N. J. (2005). Practice, instruction and skill acquisition in soccer: challenging tradition. *J. Sports Sci.* 23, 637–650. doi: 10.1080/02640410400021328

*Witkowski, Z., Lyakh, V., Gutnik, B., Lipecki, K., Rutowicz, B., Penchev, B., et al. (2011). Corrective effects of different training options on development and maturation of professional motor skills from dominant and non-dominant legs of young soccer players. *J. Phys. Educ. Sport* 11, 291–299.

Wulf, G., and Shea, C. H. (2002). Principles derived from the study of simple skills do not generalize to complex skill learning. *Psychon. Bull. Rev*. 9, 185–211. doi: 10.3758/BF03196276

*Zago, M., Giuriola, M., and Sforza, C. (2016). Effects of a combined technique and agility program on youth soccer players' skills. *Int. J. Sports Sci. Coach.* 11, 710–720. doi: 10.1177/1747954116667109

Zouhal, H., Hammami, A., Tijani, J. M., Jayavel, A., de Sousa, M., Krustrup, P., et al. (2020). Effects of small-sided soccer games on physical fitness, physiological responses, and health indices in untrained individuals and clinical populations: a systematic review. *Sports Med.* 50, 987–1007. doi: 10.1007/s40279-019-01256-w

*References marked with an asterisk indicate studies included for systematic review.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Sports and Active Living

METHODS
published: 21 March 2022
doi: 10.3389/fspor.2022.780767

Lessons From Special Forces Operators for Elite Team Sports Training: How to Make the Whole Greater Than the Sum of the Parts

Nathalie Pattyn[1,2*], Jeroen Van Cutsem[1,2], Emilie Lacroix[1,2], Martine Van Puyvelde[1,3], Aisha Cortoos[1,2,4], Bart Roelands[2], Veerle Tibax[5], Emilie Dessy[1], Magali Huret[6], Gerard Rietjens[2,7], Maarten Sannen[8], Robert Vliegen[8], Jean Ceccaldi[8], Jérémy Peffer[8], Ellen Neyens[9], Nathalie Duvigneaud[10] and Damien Van Tiggelen[10,11]

[1] VIPER Research Unit, LIFE Department, Royal Military Academy, Brussels, Belgium, [2] Human Physiology and Sports Physiotherapy Research Group, Vrije Universiteit Brussel, Brussels, Belgium, [3] Brain Body and Cognition Research Group, Department of Psychology and Educational Sciences, Vrije Universiteit Brussel, Brussels, Belgium, [4] Brainwise Ltd, Overijse, Belgium, [5] Directorate General Human Resources, Department of Defence, Brussels, Belgium, [6] Centre for Mental Health, Military Hospital Queen Astrid, Brussels, Belgium, [7] Korps Commandotroepen, Dutch Defence, Roosendaal, Netherlands, [8] Special Forces Group, Belgian Defence, Brussels, Belgium, [9] Medical Regional Centre in Beauvechain Air Base, Belgian Defense, Brussels, Belgium, [10] Centre for Physical Medicine & Rehabilitation, Military Hospital Queen Astrid, Brussels, Belgium, [11] Department Rehabilitation Sciences, Faculty of Medicine & Health Sciences, Ghent University, Brussels, Belgium

OPEN ACCESS

Edited by:
Hugo Borges Sarmento, University of Coimbra, Portugal

Reviewed by:
Philip Edward Kearney, University of Limerick, Ireland
Naroa Etxebarria, University of Canberra, Australia

***Correspondence:**
Nathalie Pattyn
nathalie.pattyn@vub.be

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Sports and Active Living

Received: *21 September 2021*
Accepted: *13 January 2022*
Published: *21 March 2022*

Citation:
Pattyn N, Van Cutsem J, Lacroix E, Van Puyvelde M, Cortoos A, Roelands B, Tibax V, Dessy E, Huret M, Rietjens G, Sannen M, Vliegen R, Ceccaldi J, Peffer J, Neyens E, Duvigneaud N and Van Tiggelen D (2022) Lessons From Special Forces Operators for Elite Team Sports Training: How to Make the Whole Greater Than the Sum of the Parts. Front. Sports Act. Living 4:780767. doi: 10.3389/fspor.2022.780767

This methodology paper describes the design of a holistic and multidisciplinary human performance program within the Belgian Special Forces Group, the Tier 1 Special Operations unit of the Belgian Defense. Performance management approaches in the military draw heavily on sports science. The key component of the program design described here is its integrative nature, which team sports training might benefit from. The basic rationale behind the program was to bridge several gaps: the gap between physical and mental training; the gap between the curative or preventive medical approach and the performance enhancement approach; and the gap between individual and team training. To achieve this goal, the methodology of Intervention Mapping was applied, and a multidisciplinary team of training and care professionals was constituted with operational stakeholders. This was the first step in the program design. The second step took a year, and consisted of formal and informal consultations, participant observations and task analyses. These two first stages and their conclusions are described in the Method section. The Results section covers the next two stages (three and four) of the process, which aimed at defining the content of the program; and to test a pilot project implementation. The third stage encompassed the choice of the most relevant assessment and intervention tools for the target population, within each area of expertise. This is described extensively, to allow for replication. The fourth and last stage was to "test drive" the real-life integration and implementation of the whole program at the scale of a single team (8 individuals). For obvious confidentiality reasons, the content data will not be reported extensively here. Implications for wider-scale implementation and tie-back to sports team training are presented.

Keywords: team performance, special forces, multidisciplinary, team sports, sports physiotherapy, performance psychology

INTRODUCTION

Context: How Sports Science and Special Operations Support Relate

Special Operations differ from conventional military operations in "the degree of physical and political risk, operational techniques, modes of employment, independence from friendly support, and dependence upon detailed operational intelligence," as described by Day and Horn (2010). Accordingly, Special Operations Forces (SOF) personnel require skills and abilities above and beyond those from members of the general body of the military, sometimes to the point of contradiction: whereas a conventional member is expected to fit in an overall framework and hierarchical structure governed by a well-defined set of rules, a SOF operator is expected to be able to switch between the latter, and the ability to creatively think out of the box in an extremely self-sufficient manner when all well-defined rules have failed. Indeed, SOF personnel are expected to be able to function in small teams, self-reliant, and independent, hereby making the team the smallest unit of performance of such structures.

The Special Forces Group (SF Gp) is the Tier 1 SOF (Special Operations Forces) unit of the Belgian Defense. Its members are selected rigorously on mental and physical capacity and the qualification course to join lasts for 6 months. It is the military training where attrition is the highest (around 80%), yet only the first quarter of the grueling complete training of an operator. This lengthy selection is based on the search for extreme physical fitness and endurance, intrinsic motivation, and mental toughness (Pattyn and Vliegen, 2019). The essence of the unit is simple: technical skills, physical endurance and mental strength make the difference between life and death; therefore, training is never complete. Operators are thus, by definition, a very limited number of elite military personnel with a very high operational readiness level. In 2017, the unit set out to design a customized human performance program for its members. The current paper is a report of the design and implementation of this program.

Despite the fact that several scientific publications (e.g., Farina et al., 2019) underscore the multidimensional (as in, linking physiology and psychology) nature of a successful selection of suitable candidates, the training and monitoring of the SF "tactical athlete" is still largely looked upon as a dichotomy: strength and conditioning for the healthy, medical rehabilitation for the injured. As underscored by Lunasco et al. (2019) regarding a new Human Performance Optimization (HPO) concept for the US SOF community: "HPO is defined as the process of applying knowledge, skills, and emerging technologies to improve and preserve the capabilities of SOF personnel to execute mission essential tasks[...]. If we adopt this framework, however, we must move beyond the current illness-based model of care and adopt or create a more suitable structure and scope of practice."

Performance enhancement coaching is another area where SOF support needs to draw on sports science. Whereas, the performance enhancing aspects of coaching have been known in the sports world for decades, the first formalized program in SOF communities has been publicized in 2017 (Barry and De Vries, 2019), which is remarkably late. Mattie et al. (2020) were the first to report the design and implementation of a specific mental skills training program for a SOF environment. Training and performance management in SOF support are usually physiology-centric, and based on training models for elite athletes. However, differences between athletes and operators have already been identified and summarized (see **Figure 1**).

The two main differences regarding training between an elite athlete and a SOF operator are, firstly, the fact that an elite athlete can focus on a very narrow spectrum of performance related to his/her discipline, whereas a SOF operator needs to excel in a multitude of domains; and secondly, the fact that the tapered training of an athlete, who works up his/her performance toward important milestones does not apply to an operator, who needs to be ready all year round. Operators are athletes who cannot follow a periodised or fixed training schedule for a single type of physical activity, such as other professional athletes. In this regard, the athletes that are closest to operators regarding training demands are those practicing team sports. The all-round type and all-year-round readiness athletic profile of the operator requires specific skills and readiness. Regarding the physical performance, primary, and secondary musculoskeletal injury prevention is paramount and therefore a tailored, and more importantly, an individualized screening and corrective training/rehabilitation program is needed. Again, similarly to team sports, where a team usually comprises members with a previous medical history of wear and tear musculoskeletal pathology, the approach to training for operators needs to take into account this injury management as well, in function of individual vulnerabilities. In order to achieve this individual adaptation, a musculoskeletal screening needs to comprise the joint mobility, flexibility, neuromuscular control, muscular endurance, and strength. The purpose is to get data to adapt individual training and perform an individualized follow-up during the whole operator's career. Regarding the mental performance, the rationale is similar: the specific demands of the year-round readiness in cognitively and emotionally demanding situations require specific skills and a specific mindset, developed and followed-up at an individual level, taking into account each person's strengths and weaknesses. This paper describes the detailed screening and assessment methods used in the Belgian Special Forces Group to develop a tailored human performance management program.

Rationale: Should Performance Management Start With Overcoming Duality?

Traditionally, both in military elite units and in elite sports science, enhancing performance has focused on the physical component of performance by relying on exercise physiology: how to boost training in order to allow for the individuals to overcome the limitations of human physiology, both in terms of strength and endurance. In the past decades, both environments have acknowledged a growing role for the mental component of performance.

The mind-body opposition in our Western tradition of thought can be traced back to the French philosopher René Descartes in the XVIIth century. It was in 1641 (Descartes, in Khodoss, 2004) that cartesian dualism was formalized by its

"Prepared for Competition"	vs.	"Constantly Prepared"
Athlete	**Training Considerations**	**SF Operator**
Planned	Schedule	Highly Varied
Specialized	Specialization	Universally Proficient
Based on Event	Peak	Not Possible
Based on Event	Taper	Very Difficult
Yes	Individualization	Limited
Between Events/Off Season	Recovery	Little to None
Controlled Venues	Location	Highly Varied

FIGURE 1 | Summary of the differences regarding training between elite athletes and SOF operators. Adapted from Solberg (2017).

author, creating a rift between mind and body, with which we are still struggling nowadays (Pattyn, 2009). Despite "mental fatigue" being the latest revolution in exercise physiology (for a review of how this demonstrates a lag compared to other research fields, see Pattyn et al., 2018), training and coaching still rely heavily on physiology, as demonstrated by sports science curricula, the composition of multidisciplinary teams surrounding professional athletes, or even the amount of training devoted to psychological skills (e.g., Otte et al., 2020).

The mind-body opposition is not the only dualism plaguing performance management. There are two others which are even lesser known and acknowledged. The second one is the dichotomy between "injured/ill" and "healthy." Current models of performance management often place performance optimization at the extreme end of good health (e.g., Lunasco et al., 2019), hence sayings like "being in the blue" or "staying left of boom," referring to the spatial orientation or the color coding of this continuum. However, this is based on the assumption that performance is an enhanced state of health. Looking at evidence both from elite soldiers and top athletes, it shows clearly that high performers can have a pathology category of their own, both on the physiological and psychological dimensions, without even touching upon the potential intrinsic pathology of overachievement (e.g., Nixdorf et al., 2015).

The third opposition is not readily perceived as such, but it is a dichotomy where it should be a continuum: the opposition between the individual and the team, when it comes to selection, diagnostics, monitoring, and interventions. On the one hand, there is a growing interest in the medical field for customization and individual differences approach, with personalized medicine being the epitome of this evolution. On the other hand, there is a whole body of research on team performance, with a systemic approach of team roles and team cognition; and this area being a research and expertise topics in its own right (e.g., in aviation or the military). However, there is still a gap to bridge between those two extremes. As some recent publications from the sports science field emphasize: we might need to move away from training and toward synergizing our elite teams (e.g., Soltanzadeh and Mooney, 2016; Pol et al., 2020). This holds true for both SOF support and sports science (and any high-performance environment where the smallest unit of performance is not an individual but a team).

Team Training in Sports Science: From the Individual Athlete to the Team

Sport training is the process of systematically performing exercises to improve physical and cognitive abilities and to acquire specific sport skills (Impellizzeri et al., 2019). When delivered appropriately, training produces a functional adaptive response that induces shifts in various training outcomes such as physical, technical and/or tactical performance, injury resistance, or health (Impellizzeri et al., 2019). Important differences in training philosophy and approach arise when individual and team sports are compared. An athlete practicing an individual sport often peaks toward one or more short competition periods, whereas typically team sport players are required to perform throughout an entire (and long) season, which is more similar to the level of readiness required from operators. The divergent goal set for the individual athlete or the team infers training content and schedules to be adapted toward achieving that goal. Hence, there is an important role for planning and periodization, recovery (internal and external), load monitoring, and medical follow-up. In team training, variation and periodization are widely acknowledged as crucial to optimizing the training responses (Gamble, 2006). Training variation is an absolute must to alleviate the monotony that can otherwise affect compliance throughout a long season of training and competition (Gamble, 2006). In general, periodization in team sports has been described as built up of several phases, starting with a mandatory preparatory phase, a competitive phase, and a transition phase in which emphasis is on full physical and mental recovery after a competitive season (Lyakh et al., 2016). Team sports coaches face an additional issue with the integration of different goal sets. The variety of training goals throughout a season (such as important games for the club; international games) and between the players (depending on position on the field and current state of fitness or injuries), as well as the extended duration of competition, pose unique challenges to periodized planning (Gamble, 2006).

In recent years the concept of training has been, and still is, revisited. The general—reductionist—idea of training has always been that the individual athletes within the team should be maximally trained, leading to an optimal performance. If the same closed recipe was applied to all of the players who formed part of the team, global team performance would also be optimal (Sainz, 2020). It could however be postulated that teams should be viewed as complex adaptive systems, whose behavior evolves in response to physical and informational constraints. From this perspective, athletes and teams are conceptualized as dynamic complex systems interacting non-linearly, i.e., co-adaptively, with the environment (Pol et al., 2020). Team performance cannot be determined by summing up performance levels of the individuals composing the team (Soltanzadeh and Mooney, 2016). This innovative approach in team sports training has so far only been described at a conceptual level in the scientific literature. The current paper presents its first practical application within a SOF team.

To conclude, we set out to tailor a human performance program aimed at overcoming the dichotomy between mental and physical performance; between care for existing injuries and performance optimization; and between individual training and team functioning. In the next "Methods" section, we will detail how we conceived this integrated program. As this conception entailed preliminary observation and investigations, the results of these phases are discussed in the "Method" section. In the "Results" section, we will describe the domain specific tools we applied and how we implemented them. The integration of all the concepts to reach the goal we aimed for will provide a multidisciplinary human performance program that allows for a holistic approach of the individual, not limited to a curative framework and considering the team as the smallest unit of performance of the system.

METHOD

Methodology for Program Design: Intervention Mapping

The design and implementation of a Mental Skills Training program within the Canadian SOF was described by Mattie et al. (2020) using Intervention Mapping (IM, Bartholomew Eldridge et al., 2016). IM is a method comprising six steps: (1) needs assessment, which can range from literature review to focus group consultation or participating observations; (2) identification of program outcomes and objectives, i.e., the "what do we want" stage; (3) program design, which in our case covered the selection of theory-driven and evidence-based methods and practical strategies from each professional background; (4) program production including pilot testing, which allowed to finetune and adapt the chosen methods along the way; (5) planning for adoption, implementation and sustainability, and (6) program evaluation. As emphasized by Mattie et al. (2020), IM is a valuable framework for the development of customized training and support programs for military personnel. One of the major added values of this approach is the transparency of the process, and the integration of relevant theory and evidence into program development. Furthermore, since a co-creation with the end-user was of paramount importance to us, both for ethical and practical reasons, this methodological framework seemed ideal in facilitating ongoing consultation with the end-user, hence enhancing the chances of effective implementation and user acceptance.

The current paper will cover the four first steps, which are summarized in **Table 1**. This method section will cover the two first steps and describe the needs assessment and the program objectives, which will thus include the results from these steps. The "Results" section will cover step" and step 4, and describe the practical program design, including all the necessary information for replication (i.e., the kitchen recipe); step 4 being the blueprint of implementation in a pilot project. As we will detail in the discussion, the current paper only covers step 1 to step 4. This approach and its description allow for an optimal transparency in the report of our design process: our aim is to present what we designed (the kitchen recipe) and why and how we designed it (hence providing the rationale behind each choice).

Step 1: Needs Assessment

Team Composition to Design the Program

As described in the introduction, one of our core assumptions was the need for true multidisciplinarity within the program, as from the start. Furthermore, we applied the principles of system theory in the design of the program: the support to be offered could not be defined by external experts only, but had to be a non-hierarchical co-creation between the expert and the actual "client" (McTaggart, 1991; McIntyre, 2007; Gergen and Gergen, 2008), being in this case the unit in itself, and more specifically, the active operators (Soltanzadeh and Mooney, 2016).

The choice of the multidisciplinary professional experts to be included in the design and implementation team was based on three criteria: (i) professional expertise in the core specialty; (ii) relevant operational military experience allowing for an efficient leverage of said professional expertise; and (iii) choice of the unit. The third criterion is subjective, yet of paramount importance to build the trust relationship necessary in this process. These experts comprised one medical doctor (MD), one performance psychologist, one clinical psychologist, three physiotherapists, and one exercise physiologist. The operational members of the unit who participated in the program design were the RSM (Regiment Sergeant Major), who is the senior NCO of the unit, and who at that time was the operator with the longest operational career in the unit; the senior medic, who was also an active operator; the unit's physical training instructor (PTI); and the team leader of the team who volunteered for the pilot project implementation.

Observation and Analysis

An international benchmarking consultation was initiated by the project team, in order to identify successful strategies in partner countries, and request support in the program design where available. In 2017, CANSOFCOM, the Canadian Special Operations Forces Command hosted a Human Performance

TABLE 1 | Overview of the four first steps of the Intervention Mapping methodology applied to the current project design.

Methods	
STEP 1 Needs assessment	• Establish a multidisciplinary expert and stakeholders team to design the program. • Determine the current needs based on real-life participant observation and analysis.
STEP 2 Determine program objectives	• Setting-up the program within a holistic approach regarding health and performance. • Define an individualized tailor-made approach to customize the whole support. • Address physical activity, nutrition and sleep needs to facilitate healthy lifestyle choice and performance improvement. • Support injury prevention and healthy coping mechanisms.
Results	
STEP 3 Program design according to each area of expertise	• Physiotherapy ○ Identify body regions discomfort and potential musculoskeletal injuries through a first screening questionnaire. ○ Provide an overall whole body functional movements assessment. ○ Offer a detailed assessment for specific injuries involving lower back, cervical or lower/upper limb dysfunctions. • Physical training ○ Define a detailed individualized physical performance assessment. · Provide a specific, validated and practical test battery · Create an evaluation tool to be used by the PTI, the operator and the physiotherapists. ○ Provide individualized physical training programs. ○ Adapt specific nutrition and hydration knowledge to the particular constraints of the population. • Performance psychology ○ Determine the specific psychometry assessment need. ○ Specify the most adequate validated trait and state assessment tools. ○ Provide a customized individual feedback. ○ Dispense a team workshop to provide feedback and determine possible interventions
STEP 4 Implementation in a pilot project	• Conceive a modular training program about the impact of human factors on the individual and team functioning. • Integrate an evolution from individual functioning to team functioning; and from participant operator receiving expert advice to autonomous actor of their own performance management. • Distribute the program throughout the year, according to the modular built-up principles discussed earlier: ○ Four weeks at the unit (January – April – June-December) ○ Two deployment periods (3 weeks/3 months) with embedded experts.

Step 4 is further detailed in Table IV.

Symposium aiming to provide this international benchmarking and collaborative networking. Following the attendance and networking, support was requested and obtained from the Netherlands, regarding the design of the physical assessment, training, and nutrition part; and from Canada regarding program design and implementation on the one hand; and mental performance on the other hand. In the meantime, the Canadian team published their program design approach in 2020 (Mattie et al., 2020).

Rather than limiting the activities of the design team to consultation meetings, which we feared would have created the risk of disconnecting the design process from the shop floor experience of the operators, we chose to anchor the process in the reality of the unit, through participant observation (Jorgensen, 1989; Spradley, 2016). Over the course of 1 year, several of the professional experts (only those with an active duty status) were included in operational deployments (exercises, courses, and actual missions) of the unit. These included portions of the qualification course, the counter-terrorism course, the personal and vehicle security course, two international exercises, and one mission in a conflict zone. Each professional fulfilled a support function during these observations, to feed the program development with real-life needs assessments.

The first issue which was consistently named by all consulted members of the unit regarding their performance management was the prevalence of musculoskeletal injuries. The physiotherapists thus conducted an in-depth screening with 60% of all active operators to quantify the problem and thus inform the program design. From all the screened operators, 88% showed either chronic or recurrent musculoskeletal issues, despite their active duty professional fitness qualification. This “active duty fitness” is a highly demanding occupational medical screening, aimed at medical risk mitigation for frequently deployed personnel, especially in combat functions. The prevalence information regarding musculoskeletal injuries was only obtained because of the confidentiality guarantee toward the operators. The further description of assessment and diagnosis is detailed in the “Results” section.

One of the support functions which was the least used and known by the active operators at the beginning of this process was clinical psychology. In order to define in which way this function could answer the needs, an exploratory survey was conducted through individual interviews with 52% of all active operators within the unit. This allowed to have a better grasp on the risk factors for their mental health and well-being from their own perspective. The results of this survey have been published elsewhere (Huret, 2018), however, they were recently confirmed by Frueh et al. (2020), in their results describing the medical and behavioral healthcare needs of a special forces population in the US military.

Step 2: Program Objectives

The second step of the IM approach involves determining the desired outcomes that should occur as a result of program implementation. In this definition stage of the program objectives, a first field of tension was identified, in the question whether the program was actually advocating for individuals’ interests (i.e., the active operators) or institutional interests (the unit or on the larger scale the Department of Defense). This ethical issue will be further addressed in the discussion. For the current program development, the choice was made to always prioritize the interests of the individual operators. A practical example was the confidentiality of the results of assessments made in the framework of the program. From the start, the design team determined that those results could not be part of the official medical service record of the operators, in order to preserve the trust relationship to be built with operators.

Program objectives are defined here as design requirements, not as quantifiable performance indicators for the outcome in terms of operators' performance. The difference lies in what in medico-legal terms is defined as an obligation of means vs. an obligation of results. The program design objectives are thus defined regarding what the project team identified as requirement for the program, based on the needs assessment.

A Holistic Program

According to the operators, being one is not a profession, it is a way of life. Hence the necessity, as acknowledged by other programs (e.g., Lunasco et al., 2019) to address mental and physical health and well-being, in both the professional and personal aspects of life. This further supports our initial choice of multidisciplinarity; and of the systemic approach regarding mental health. This aspect holds true for elite athletes as well: the commitment to training and performance is of such magnitude that it does not allow for a compartmentalized life.

Capitalize on Strengths

From an institutional point of view, a defining feature of the Belgian unit compared to partner nations is its small size. Whereas, this could be viewed as a weakness, in terms of availability of resources and leverage, it is also a strength, as it allows for an individualized approach, customizing the whole support offer to the specific needs of each individual and each team. This is also the case in professional team sports, where the support teams knows each athlete individually, and where the whole work is organized in a tailored fashion to that specific setting. As such, our experience might be more relevant to sports team training than that of larger nations, where the "client population" amounts to hundreds of people.

From an individual point of view, defining features of an operator emerged from our consultations and observations performed during Step 1: an individual with an exceptionally high need for achievement, sense of self-discipline and need for autonomy (Huret, 2018). These features need to be leveraged as cornerstones of the approach; and further justify our original choice of early stakeholder involvement considering the need for autonomy of operators.

Facilitate Healthy Lifestyle Choice, Sustaining Performance Improvement

We identified a 3-fold gap in the application of the World Health Organization's "Pillars of Health" (i.e., physical activity, nutrition, and sleep): lack of education, lack of support and guidance, and lack of material availability (as in healthy food, equipment or space for training, reach back to experts providing guidance etc). Physical activity is so paramount in both the function of the operator but also his coping mechanism (Huret, 2018) that we addressed it separately. Regarding nutrition and sleep, as there were no institutional programs within Defense in these areas at the time, we distributed them within the experts team: nutrition would be addressed by the Dutch exercise physiologist consulting for the program (who had the expertise of implementing a nutrition optimization program within the Dutch SOF unit, e.g., Rietjens et al., 2021), the MD and the physical training instructor (PTI); and sleep would be addressed by the MD (who had the expertise of decades of research regarding sleep in extreme environments, e.g., Pattyn et al., 2018) and the performance psychologist. Lack of education was addressed in our pilot project, as well as lack of support and guidance. Lack of material availability could not be fully met, as procurement (of equipment or food for example) may be well above the level of responsibility of the unit. The detailed program to address these issues is summarized in Step 4.

Address Vulnerabilities

The multiple stressors and professional demands to which operators are subjected have been extensively described elsewhere (e.g., Huret, 2018; Pattyn and Vliegen, 2019; Mattie et al., 2020). However, two main intervention axes were identified in the needs assessment (which was the first step of our program design): the physical wear and tear, sometimes described as the "shelf-life" of the operator; and the existing coping mechanisms to deal with these exceptional stressors. Since these intervention axes were guiding red threads in the design of our program objectives, we describe them in this section.

Physical Wear and Tear

The staggering prevalence of 88% for musculoskeletal issues has already been mentioned. Considering the fact that physical performance is a basic requirement for the job of operator, injury prevention and management has to be a key component of the program. Furthermore, for the personal well-being and overall life satisfaction of operators, this ability to function pain free in their personal life (carrying children, practicing sports, transitioning to another profession without physical limitations) is a major concern.

Support Existing Coping Mechanisms

Operators thrive in a context where many "normal" individuals would feel uncomfortable. Therefore, part of the initial survey regarding mental health and attitudes toward psychological support was to map their coping mechanisms, in order to identify which could be further supported. Three main factors of healthy coping mechanisms were identified in the individual interviews: sports practice (for 100% of the interviewed operators), partner relationships (88%), and team dynamics (50%). For the program design, we thus focussed on developing support for these three domains. Furthermore, considering the specificity of the SOF professional environment, the reliance on the team as the basic unit of functioning, and the long durations of deployments for courses, exercises and missions, it was important to make members partly self-sufficient in their performance management. As we already emphasized previously: the need for autonomy is one of the core features of individuals in SOF, hence our leveraging of this feature in our program design approach. Similarly to what is implemented regarding medical care (NATO SOF Medical standards and training directive, 2009), where operators have the most in-depth training for non-medical personnel regarding technical procedures and access to pharmacological treatments, because of their need to function in a self-sufficient manner, we set out to design tools that could enable them, once a period of basic psycho-education and implementation testing was fulfilled, to provide the first line of care for themselves.

The next section, "Results," will describe the two next steps in our IM project design: the actual fulfillment of these requirements, with the practical content of the program design. Since the approach for this program was to map individual strengths and weaknesses to build a team training upon, the first step was to select the relevant individual assessment to work with. The next section will describe these assessments in detail, as well as the rationale behind the respective choices.

RESULTS

Step 3: Program Design According to Each Area of Expertise

Physiotherapy

According to the framework discussed before, the physiotherapy approach is centered around individualization. A first challenge resided in the combination of injury prevention and treatment on the one hand; and performance enhancement on the other hand. Considering the fact that 88% of all screened operators in our population reported chronic musculoskeletal issues, this clinical approach is necessary to allow for a continued physical training without enhancing the existing problems. To allow for a rational workload distribution, the assessment of operators is layered and modular, which we will detail below (see also **Figure 2**).

Layer 1: Screening

Operators completed a short version of the Dutch Musculoskeletal Questionnaire (DMQ) category health 2, to identify the body regions with pain or discomfort (Hildebrandt et al., 2001; Southerst et al., 2013). As previous injuries are the utmost important risk factor for future injuries, this history is carefully recorded (Fulton et al., 2014). Post-injury assessments demonstrate for example modifications in strength, proprioception, motor control and even kinematics, which are known risk factors of clinical importance in sports injury prevention (Parr et al., 2015).

Layer 2: Overall Clinical Assessment Through Selective Functional Movement Assessment

Impairments associated with musculoskeletal injuries are rarely confined to the injured joint, and residual deficits can persist if these impairments are not addressed properly. These deficits and remote dysfunctions are not easily identifiable by traditional, joint-specific examination techniques. Therefore, we selected the Selective Functional Movement Assessment (SFMA), a movement-based functional assessment model, to be performed on all operators to identify weak links affecting overall functions and estimate injury risk (Glaws et al., 2014; Goshtigian and Swanson, 2016). Data were collected by trained military physiotherapists from the Military Hospital Queen Astrid (Brussels, Belgium) to uncover insights about actual and former pain experiences and functioning. Clinical tools like SFMA that incorporate whole body functional movements may uncover important underlying impairments that allow for the development and implementation of targeted interventions to both maximize recovery after primary injury and prevent secondary injury (Glaws et al., 2014).

With the SFMA the therapist assesses posture, muscle balance, and movement patterns in order to identify relevant musculoskeletal dysfunction in a clinical population. It guides physiotherapists to dysfunctional movements not seen with more conventional examination procedures (Goshtigian and Swanson, 2016; Fauntroy et al., 2019).

Using the SFMA Categorical Scoring tool, each basic Top Tier test is graded as Functional and Non-painful, Functional Painful, Dysfunctional Non-painful or Dysfunctional Painful. If a Top Tier test does not pass the "Functional Non-painful" grade, then that specific movement must go to a breakout pattern to find the root cause of dysfunction. The "true cause of the dysfunction" can be a tissue extensibility dysfunction, a joint mobility dysfunction, or a stability/motor control issue (Goshtigian and Swanson, 2016; Fauntroy et al., 2019).

After the categorical scoring, subjects are assessed by the criterion checklist assigning an ordinal scale rating to each top-tier movement. A score of zero indicates perfect performance without compensation for all movements. A total score of 50 indicates failure of all criteria (Dolbeer et al., 2017; Kim and Do, 2021).

Layer 3: Detailed Breakout Assessments

Based on body pain diagram outcome, medical history and the SFMA test results, the operators were referred to one or more detailed test batteries carried out to further analyse lumbar, sacroiliac, cervical, lower limb, or upper limb dysfunctions. These additional tests enabled further identification of inefficient compensatory movement tendencies, muscular weaknesses, lack of motor control and stability, as well as lack of flexibility. This level of examination is only carried out for subjects for which more insights are needed and not routinely to everyone. As this third layer requires more technical devices such as isokinetic dynamometers, surface electromyography or pressure plates, these assessments are performed in laboratory conditions in the military hospital.

Layer 3A: Detailed Test Battery for Lower Back Dysfunctions

The test battery for lower back dysfunctions includes low load movement control tests like single and double knee extension in sitting, hip flexion in sitting, hip extension instance, and standing bow (Stevens et al., 2006; Van Damme et al., 2014), muscle extensibility tests (Lopes et al., 2021) and hip abductor strength test (Nadler et al., 2001). Additional isokinetic strength tests (trunk flexion and extension) and a 16-channel surface electromyography of the trunk muscles provided further insights if more high load and/or muscle endurance testing was needed.

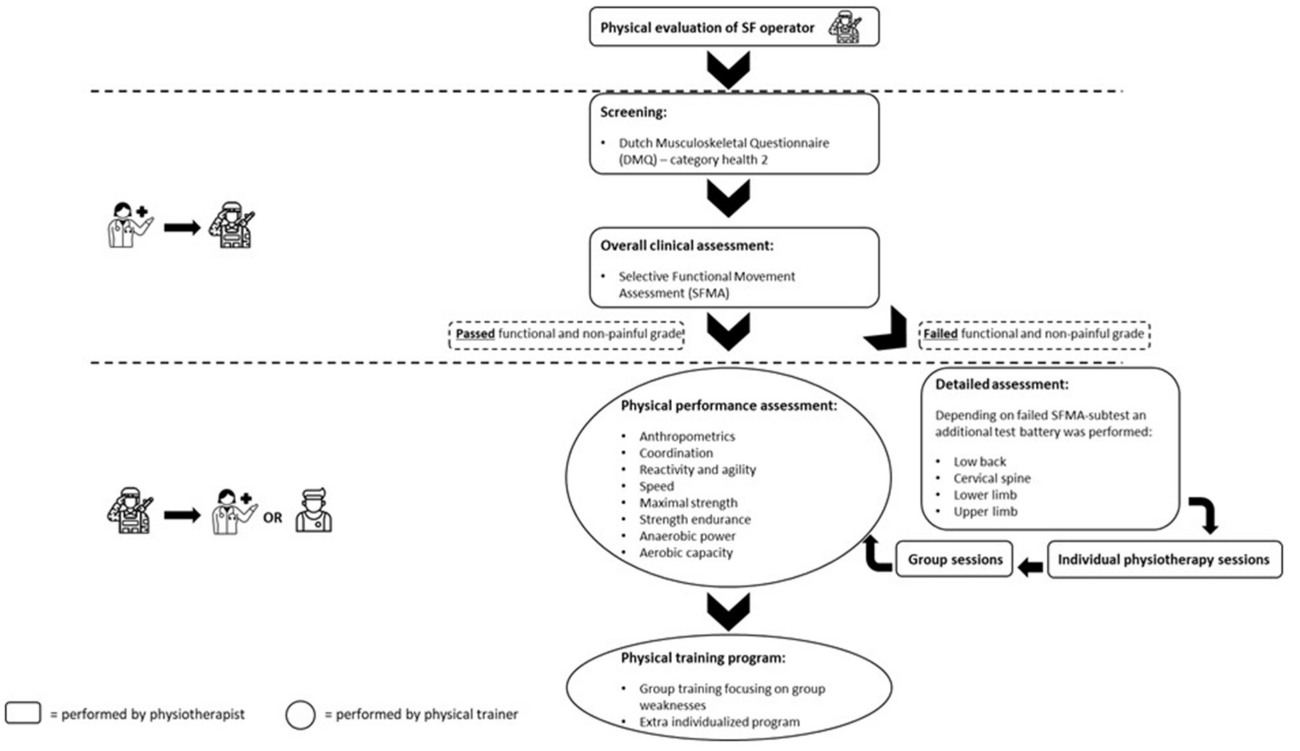


FIGURE 2 | Flow chart of the physiotherapy assessment and transition to the physical training instructor evaluations. "Screening" and "Overall clinical assessment" are performed by the physiotherapist in the unit, "Detailed assessment" in the Center for Physical Medicine and Rehabilitation of the Military Hospital Queen Astrid and the "Physical performance assessment" is done by the unit physical training instructor.

Layer 3B: Detailed Test Battery for Cervical Dysfunctions

The test battery for cervical dysfunctions consisted of a broad spectrum of tests (Falla et al., 2004). Similar to all other body areas, the aim was to specifically address various impaired physiological functions, to propose a multimodal training regime (Blanpied et al., 2017).

Cervical ROM measurements for flexion, extension, lateral flexion, and rotation as well as proprioception were evaluated with Zebris, a 3 D-movement analyser (Zebris Medical GmbH, Isny, Germany). Mobility and proprioception were compared to normative data from a healthy military population within the same age and sex. The same applied for measurements of maximal isometric strength of neck flexors, extensors and lateral flexors with the David Back Dynamometer (Sihawong et al., 2011).

Thoracic posterior-anterior pressure tests were applied to investigate if there was thoracic involvement (Young et al., 2014). Observation of scapular (dys)function during arm anteflexion and abduction determined if cervico-scapulothoracic strengthening/stabilization exercises could be recommended (Helgadottir et al., 2010).

To address motor control of the cervical spine, segmental assessment was carried out by performing cranio-cervical flexion tests and deep sub-occipital extensor tests (Falla et al., 2004). Control of direction included low cervical flexion control-nodding and overhead arm lift, upper cervical flexion control-head forward lean and arm extension test, global rotation-sidebend control, neck global sidebend—rotation control, and upper cervical sidebend—upper neck tilt (Khosrokiani et al., 2018; Comerford and Mottram, 2019).

Layer 3C: Detailed Test Battery for Lower Limb Dysfunctions

The test battery for lower limb dysfunction comprised analytical mobility tests for hip, knee, ankle, and the first metatarsophalangeal joint. Hamstrings, hipflexor, hipadductor, hipabductor, and triceps surae extensibility tests were done as well, bearing in mind that flexibility plays an important role in reducing the risk for lower extremity musculoskeletal risk in special operation forces (Keenan et al., 2017).

Single leg stance static and dynamic control while reaching maximally with the other leg was evaluated during the Y Balance Test (Gribble and Hertel, 2003; Bressel et al., 2007). Additionally, tests for motor control during hip rotation, hip extension, heel walk, and stair descend followed for assessment of quality of movement (Herman et al., 2016; McGovern et al., 2018; Christopher et al., 2019).

Plantar pressure plate recording was performed [Footscan, RSscan Int, Paal (Belgium)]. It has been demonstrated to be useful to identify risk factors for overuse injury in a military population (Franklyn-Miller et al., 2014).

Maximal knee-extension and flexion strength (concentric and eccentric) were quantified using an isokinetic dynamometer.

Knee-extension strength deficit is a known risk factor for musculoskeletal injury in operators (Barber et al., 1990).

Layer 3D: Detailed Test Battery for Upper Limb Dysfunctions

Research demonstrates that operators with a previous history of shoulder pain have less shoulder strength than uninjured operators (Parr et al., 2015). Therefore, concentric strength of internal and external shoulder rotators in 90° shoulder abduction was measured using an isokinetic dynamometer.

Further, scapula position (protraction, tilting) as well as scapular dynamic control during arm elevation and abduction was assessed. Anterior, posterior, multidirectional instability tests as well as load shift test were run and rotator cuff function of supraspinatus, infraspinatus and subscapularis was evaluated (Tennent et al., 2003; Lizzio et al., 2017). Additional detailed assessment of the elbow, wrist, and fingers was performed if needed (i.e., if operators had indicated issues regarding these locations in the screening questionnaire). Neurogenic testing, such as upper limb nerve provocation tests, was performed to collect detailed data subsequent to the clinical reasoning process of the therapists and concordant to the data collected in layer 2 (Nee et al., 2012). The sustained grip, pinch strength, and also range of motion in fingers and wrist was assessed using the Biometrics E-link (Biometrics Ltd, Newport, UK).

Conclusion Regarding Physiotherapy

In order to prevent and/or rehabilitate musculoskeletal problems in Special Forces operators, physical functioning was analyzed. 88% of all tested operators reported chronic or recurrent musculoskeletal symptoms, but it did not hold them from their professional occupations. A mean of three injuries or impairments are observed for each operator. One third are upper limb impairments (33%) which are more present in operators than in other military personnel. 31% of all injuries are located in the lower limb, 25% in the lumbar spine and 11% cervical spine impairments are observed. Therefore, over 80% of the screened operators were addressed to at least one of the layer 3 pathways.

As stated in the introduction, operators are, by definition, a small number of elite military personnel with a very high operational readiness level. This does not mean that those soldiers do not have to cope with injuries and consequences of past injuries. Over four out of five operators demonstrate musculoskeletal pain and/or dysfunctions impairing their physical readiness. Even without numerical comparisons, the management of a team of athletes will create similar conditions. In order to improve the readiness level, adding specialists in musculoskeletal rehabilitation and injury prevention in the day-to-day support to operators and athletes is paramount.

Feedback on test results immediately followed the screenings; corrective exercise programmes including stretching, muscle strengthening, motor control exercises, and/or manual therapy were provided to each operator individually. Exercise programs can both be monitored—and adapted—in the unit during consultations or remotely by the use of mobile applications. For the conception of this program, the Skill-Up (www.skill-up.com) and Physitrack (nl.physitrack.com) platforms were used to provide remote guidance and online exercise programs by the physiotherapist, in close cooperation with the PTI. The programs delivered by the physiotherapists have a focus on mobility, flexibility, motor control and strength upon which physical training programs can be further developed with an additional focus on conditioning, agility, endurance, balance, functional strength, speed, power... after an additional assessment done by the physical training instructors. This does also mean that if no major impairments are observed, an operator could skip the layers 1–3 and therefore immediately go to layer 4 (i.e., the PTI-managed level). The whole process covering the spectrum of assessment, rehabilitation, injury prevention, and customized training is detailed in **Figure 2**.

The ultimate goal of the functional musculoskeletal assessments is to create a framework for injury prevention, rehabilitation, and performance enhancement so that the operator could safely perform the movement demands of their military activities. Furthermore, considering the paramount importance for movement for this very physically active population, their ability to move pain free determines one of their main coping mechanisms (sports) and their overall quality of life.

Physical Training

As previously described, a major challenge in optimizing the physical readiness of SF operators resided in the combination of injury prevention and treatment on the one hand; and performance enhancement on the other hand. This challenge requires continuous communication between the physiotherapist and the physical trainer. The process is summarized in **Figure 2**, which also illustrates the practical application of one of the basic assumptions, being customization of training according to each operator's vulnerabilities. This need for interaction was reached by group meetings within the program team, and by sharing results of the clinical, the physical and the mental assessment. Indeed, the involvement of the performance psychologist in this physical assessment part also enabled the physiotherapist and the PTI to address issues in a way most suited to each individual, in terms of communication and leverage for behavioral change.

Physical Assessment: Rationale

Regarding physical training, the first step was to define a detailed physical performance assessment, which would be a key indicator for overall fitness; a reference to follow up training progress; and a blueprint of strengths and weaknesses to guide training. The choice of appropriate job-specific testing and training was determined by a literature review; conducting oral and written interviews with active operators; participant observations during some of the most physically demanding courses; and through international benchmarking and collaborations.

Pemrick (1999) evaluated the job demands of a comparable elite unit (i.e., the U.S. Army Rangers). Two specific missions carried out by the U.S. Rangers (i.e., a hostile raid and airfield seizure) were subjected to task analysis (Pemrick, 1999). This analysis highlighted three important physical components for the mission's success: aerobic-, anaerobic fitness and strength. Moreover, Eisinger et al. (2009) have performed a similar job analysis within the Austrian SOF community. Through further

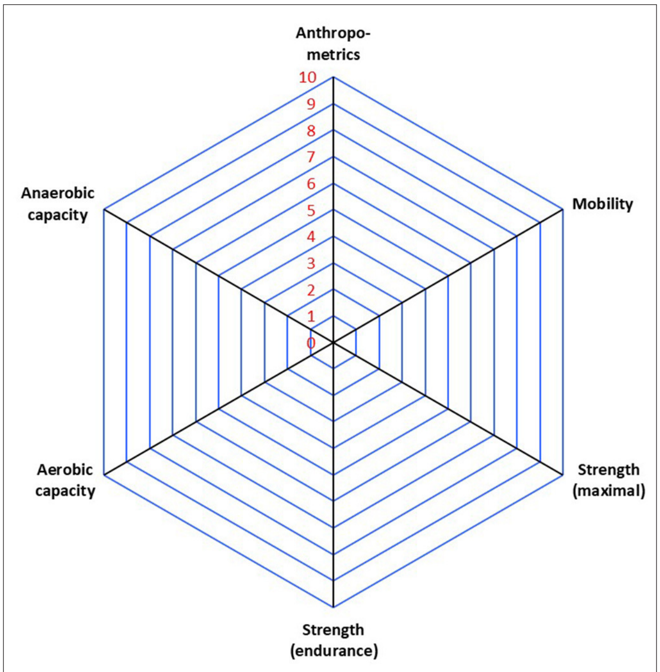


FIGURE 3 | Overview of the SF operators' physical performance key determinants, as identified based on in-the-field observations, international benchmarking, and the available literature.

task analysis of operators' specific physical tasks (i.e., close combat, using explosives, parachuting, mountaineering, survival techniques, and shooting), it became clear that coordination and reaction speed are the most dominant physical components setting this population aside. Secondly, Eisinger et al. (2009) demonstrated, like Pemrick (1999), the importance of aerobic endurance, strength endurance and anaerobic endurance for SOF's work. Based on our participant observations, the international benchmarking and the available literature, we summarized the physical key components during training and missions in SOF operations in **Figure 3**.

Following the identification of these physical performance key components, specific tests had to be selected and combined in a physical fitness test battery. To optimize our choice of physical assessment tests, we evaluated the physical fitness test batteries previously used in a SOF context (Carlson and Jaenen, 2012; Sporiš et al., 2012; Solberg et al., 2015; Abt et al., 2016) and, considering the time-constraints, evaluated each test against a number of criteria to decide whether to include it or not. These inclusion criteria were: (i) The test had to measure in a valid and reliable way what is important to the nature of the military activity. Ideally, a test had to be as specific as possible to the job. However, because of the versatile nature of the array of tasks a SOF operator -and a team sports athlete- has to perform, there is an inevitable trade-off between standardization of the assessment and representativeness of the task. Whenever possible, we would favor validated tests in exercise science, in order to enable external comparisons. As emphasized by Vine et al. (2021), we strived for a balance between external validity and experimental control.; (ii) A test had to be practical, efficient, functional, convenient, and easy to perform; (iii) The test had to be as specific as possible, i.e., able to isolate and assess one physical key component at a time, to eventually be able to pinpoint someone's weakness(es) and avoid confounding results. Tests in which different physical key components were combined were thus avoided; (iv) In contrast to elite sports, there is generally very little time for individual testing within the SOF environment, due to the operational pressure. Whereas, training is seen as a "necessary evil" by both management and individual operators, testing, which is an investment to ensure training is targeted, is often not perceived as a justifiable time investment. Therefore, the tests had to be suitable for testing larger groups simultaneously in a short amount of time.

Physical Fitness Test Battery: Description

Anthropometrics. Body weight (BW) and body fat percentage (F%) were measured by using a bioelectrical impedance analysis (BIA, TANITA-BC-418 Segmental Body Composition Analyzer), with consideration of the measurement of weight up to the nearest 0.1 kg. These variables were measured because a prolonged intensive period of training can lead to an overall negative energy balance and low energy availability (Mullie et al., 2019; Rietjens et al., 2021). This low energy availability can lead to reductions in body weight (BW) and changes in body composition, which can impact both health and performance (Tassone and Baker, 2017). During an 8-week US Army Ranger Course, body weight losses averaged 9.4% with individuals losing to up to 17.5% of their body weight. A substantial loss of 3.6% of fat-free mass was observed during a 20-day training course in Finland. These body weight and body composition reductions and their impact on performance suggest the need for a better monitoring before and after field activities (Tassone and Baker, 2017).

Mobility. Whereas, an exhaustive assessment of mobility was already performed in the clinical assessment by physiotherapist, this "on-the-go" version allowed the PTI to follow-up in any location. A selection of four tests of the Functional Movement Screening (FMS) was applied, i.e., the deep squat, hurdle step, leg raise, and shoulder mobility (including the shoulder clearing test). This control check-up could be performed by the PTI, as results of all screenings were continuously shared between physiotherapists and physical trainers.

Strength (Maximal). Four 3-repetition-maximum (3RM) tests were selected to assess maximal strength in different regions of the body where a large muscle mass is present and, in addition, to evaluate any imbalances in strength between specific body regions. The tests were leg press, bench press, vertical traction, and shoulder press.

Strength (Endurance). Strength endurance was evaluated via two bodyweight exercises, the chin-up and the Biering-Sorensen test. The chin-up test is a dynamic strength endurance test in which the number of correct repetitions was used as outcome measure. A correct repetition included crossing the pull-up bar with the chin while keeping both legs together and without moving them forward, the hands had to be placed around the pull-up bar at shoulder width. In contrast, the Biering-Sorensen test is a static strength endurance test in which the outcome measure is the amount of time one can hold the correct position. In the Biering-Sorensen test one is secured to a horizontal table in the prone position. The table only supports the pelvis and legs. The test instruction is then as follows: maintain the horizontal position for as long as possible.

Aerobic Capacity. Regarding aerobic capacity, a 2-fold approach was followed: a "field testing" including a 2800-m run and a 16-km speed march, to allow for the PTI to perform the tests almost everywhere; and a laboratory testing to determine the actual VO_2max.

The VO_2max of each operator was measured by a maximal effort test on a treadmill. Despite this test being labor intensive and environmentally constrained by the availability of the equipment, the standardized outcome, if performed once a year for example, sustains the field assessment with more precise data. The maximal protocol started at 5.4 km/h, every 3 min the velocity was increased with 1.8 km/h, with a maximum of 23 km/h. Each 3-min stage, blood was drawn from the earlobe to evaluate blood lactate concentration. Gas exchange data with the operator's oxygen intake and carbon dioxide output measured was collected using an automated breath-by-breath system (Ergocard Clinical, Software Medisoft, Belgium). The relative VO_2max was determined for maximal oxygen uptake in ml/kg/min and ml/min.

Anaerobic Capacity (Speed). The Repeated High Intensity Test (RHIET) was applied, which consists of four repetitions of a 60 m sprint. Each 60 m sprint started 30 s after the previous run. This cycle continued until four sprints were completed, starting at 30 s, 1 min, 1.5 min after the start of the first sprint. A fatigue index was calculated by taking the average time of the first two trials and dividing it by the average time of the last two trials.

Performance and Use of the Test Battery

The time required to run this test battery was around 2 h for 20 people. Three to four instructors were needed to supervise the whole process.

Commercial software is available to provide support with processing the test results. However, these are mainly made for (elite) sports and therefore not always suitable for our military arena, because of insufficient adaptability of the content. Furthermore, data security and ownership is often an issue, regarding server localizations and long-term guarantees. Lastly, use of the test battery on deployment requires a complete offline availability. For all these reasons we designed a simple MS Excel sheet to store and process the test data; and to produce an evaluation report, of which an example is provided in **Figure 4**.

The feedback of the test data was 2-fold. As an absolute number (score) for the individual; and as a percentile (10%) score in a spider diagram. In this diagram, the personal results were visualized in relation to their own peer group, being the other operators. When applied in the team training phase, this feedback allowed for the team to construct a "team report," identifying strengths and weaknesses of all team members, and already anticipating combat situations and role distributions. This stage will be further elaborated in the description of Step 4.

Individualized Training Program

Based on the results of the test battery, which were discussed within the multidisciplinary project team, the goal was to address the observed weaknesses and maintain the individual's strengths. Physical training was provided to the tested SF operators in two ways: (i) via a team training in which the weaknesses of the group in general were specifically addressed, and which was also the first stage in the team training that will be described in the specific section (Step 4); and (ii) via an individualized training that could be performed at customized times. Both group trainings and individualized training programs were developed in close collaboration with the physiotherapist and with the operators themselves, during the individual consultations. Individual feedback moments were organized with each tested SF operator. To aim for a certain level of periodization, and to determine when intensive training blocks could be performed, the PTI coordinated with the team leader, to discuss the macrocyclus of the upcoming work-related activities (exercises, deployments…). The tactical planning was thus taken into account in developing individualized training programs, and in the decision on when to focus training on addressing a specific weakness or on maintaining a specific strength, or on recovery to prepare for particularly intensive operational demands.

A specific advantage of individualizing training programs was also that it provided the ability to be more focused and therefore more time-efficient. Due to operators' operational readiness and workload, it was difficult to plan for yet another training program in their already busy schedule, an issue that was already acknowledged in previous literature (Christensen et al., 2008). Furthermore, if training is possible, their deployments do not always allow for optimal training conditions (e.g., sufficient time, sleep deprivation, lack of food intake, or the adequate facilities), which can alter their operational readiness and result in higher injury rates (Sharp et al., 2008). The high level of customization; the mutual trust relationship between the operators, the PTI and their dedicated physiotherapist; and the availability of the experts for reach back consultation during exercises and deployments were key features in the adherence to the training program.

Nutrition and Hydration

Elite forces preparation involves such metabolic demands, that daily training may require up to 6,000 kcal/day. Such high energy needs pose a major challenge to maintaining the energy balance over a longer period of time. Risks such as insufficient energy intake from carbohydrates, dehydration due to low fluid intake and the intake of poor-quality nutrition (a lot of energy, but insufficient nutrients) are lurking and can eventually lead to weight loss through muscle breakdown and significant decreases in mental and cognitive performance. In 2019, Mullie et al. published a study on energy expenditure and availability within the Belgian Special Forces qualification course. During four consecutive days, candidates undertaking the Q-course (i.e., the qualification course to become a SOF operator)

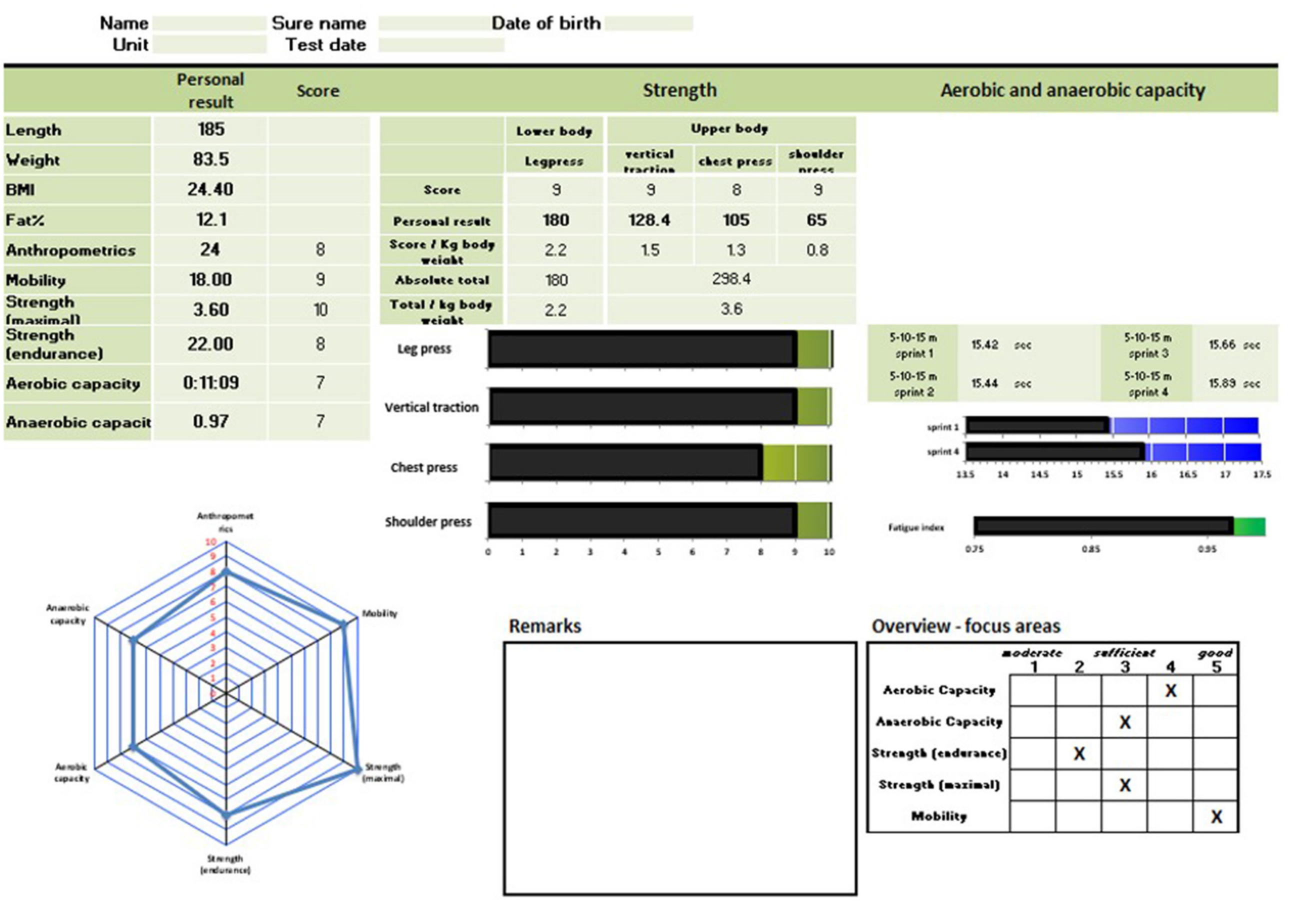


FIGURE 4 | Example of the individual feedback of the physical assessment battery, according to the dimensions described above.

were assessed. Through measuring hydration, recording physical activity and registering the intake of nutrients, important nutritional deficiencies were identified. With only 17 kcal per kg fat free mass (FFM) per day, mean energy availability was far below the recommended 40 kcal per kg FFM per day to perform in optimal conditions, i.e., without a decline in essential physiological processes (Loucks et al., 2011). When prolonged, low energy availability can lead to adverse physiological and psychological effects and impair performance and health (Logue et al., 2018).

Tackling nutrition in a Defense environment is complex, for the purchase and procurement decision is usually made higher up than at the scale of the unit. Ideally, quality and quantity of available food should be improved, by taking into account composition (macro and micronutrients), portion size, timing of offering, taste, and presentation. In the context of SOF, the main challenge is not to determine precisely how to scientifically investigate what optimum type of nutrition should be offered. Several comprehensive sources already exist that cover the topic (e.g., Deuster et al., 2017; Rietjens et al., 2021). The main issue is a practical one, which can be summarized as timing (of food intake) and availability (of food of sufficient quality in sufficient quantity).

Both Deuster et al. (2017) and Cole et al. (2018) thus acknowledge the need to educate the end-user (i.e., the operator) as the first step in improving nutrition in a SOF population. Cole et al. (2018) showed that education resulted in diet quality improvements and thus demonstrated this to be feasible to be implemented in a Special Operations Forces Human Performance Program. Since the frame of our project did not allow for a direct intervention regarding procurement or mess organization in the barracks, this was indeed the only level we could target. The implementation of this nutrition education will be described in the "Implementation section," paragraph Step 4: Implementation in a Pilot Project: A One-Year Follow-up of One SOF Team.

Performance Psychology

As discussed in the introduction, we aimed to overcome several dualisms in the performance psychology approach. We set out to evaluate the holistic subjective experience of the operator from a systemic point of view. As physical performance is of paramount importance for the professional demands of our population, it was important to encompass this aspect in the subjective evaluation. Furthermore, overall well-being at work and at home were also considered relevant. SOF operators and elite athlete both commit completely to their profession, hence the impossibility to compartmentalize their support, which is emphasized by Barry and De Vries (2019): "USASOC Strategy 2035 Campaign Plan codified the need for ARSOF to improve human/spiritual performance, behavioral health, social readiness, and resilience." As we described in the introduction and method, psychology actually knows several sub-disciplines, and the aspect of performance psychology was the product of a constant interaction within the program design team. As we discussed in the "Method" section, and considering the influence for our other variables, we have included sleep in this layer as well. Sleep and fatigue management were thus a vector of both assessments and interventions. Whereas, this domain has widely been acknowledged as a major determinant of performance in other areas, such as aviation (for a review, see Caldwell and Caldwell, 2005), it seems this subject only gained momentum in the tactical army population in the last decade (e.g., Troxel et al., 2015). Furthermore, based on our observations, this was an important area of concern. The holistic and systemic approach we applied does not only mean to add several perspectives, but also to evaluate how they influence one another on the one hand and how the individual's well-being influences the team and vice versa. Achieving this required an enhanced targeted communication toward this goal, both within the multidisciplinary project team on the one hand, and within the pilot project SOF team on the other hand. Both teams thus managed to enhance their situational awareness to the "bigger picture" and increase insight and reflection both on the process and on the content.

As described in the "Method" section, the first step was to select the relevant individual assessment to work with. We thus layered the experiential assessment in three layers: the first layer was the individual screening and mapping based on psychometry; the second layer was the customization and individualized feedback step; the third layer was the integration at team level, comprising the psychoeducation approach to the team to empower self-regulation.

Layer 1 = Overall Screening and Mapping Based on Psychometry

Two types of psychometry tools were used. The first one encompasses all the "trait"-like variables, hence considered to be stable within one individual. The second one covered the "state"-like variable, meaning situationally sensitive variables, which vary with changing resources and demands (e.g., sleep deprivation, family issue, physical fatigue etc).

Psychometry: Trait Assessments. A "trait"-like feature measure only needs to be taken once, to provide a profile of the individual. Our choice of individual psychometric tools to measure "trait" like variables was guided by three criteria: (i) the necessity to rely on validated instruments, in order to be able to interpret results against standardized norms and compare to other investigations; (ii) what we called the "bottom-up feed": the information we received from the unit, regarding the "ideal" profile of an operator in their perception, based on decades of operational experience, coupled to our year-round observation of courses and deployment integrated to the operational detachment (as detailed in the Method section), which allowed us to make an informed choice regarding target variables related to real-life performance; (iii) the available literature regarding psychometric investigations related to performance prediction in SOF. We chose to measure personality dimensions, intelligence-fluid, crystallized and emotional- and sleep traits. The following section summarizes the rationale for these variables, as well as which instruments were implemented. All testing was conducted by a trained clinical neuropsychologist and in the native language of the operators. These language variations are not reported in the current paper.

The NEO-PI-R was used to have an overall assessment of personality (Costa and McCrae, 2008). As we described earlier, operators thrive in environments that are actually extremely stressful. Several moderators, such as hardiness, can sustain this thriving (Bartone, 1999). Based on the existing literature, we opted to measure several trait-like aspects of psychological fitness, i.e., hardiness, risk-taking, and trait-anxiety.

Hardiness is a fairly stable personality trait, which has been shown to predict a successful outcome of the qualification course (Bartone et al., 2008; Hystad et al., 2010; Lo Bue, 2015). Hanton et al. (2013) examined the interaction between hardiness and anxiety and found that people who scored high on hardiness also tended to have lower levels of anxiety. Hardiness was evaluated using the Hardiness questionnaire developed by Lo Bue (2015). This questionnaire consists of 40 affirmative sentences. 24 items are "positively" connoted and measure commitment (7), control (11), and challenge (6). These three components constitute the construct of dispositional resilience. Sixteen items are "negatively" connoted and measure alienation (negative commitment), powerlessness (negative control) and rigidity (negative challenge). These three negative components constitute the construct of dispositional vulnerability. These two composite scores allow to calculate the total hardiness score.

The eagerness to be exposed to danger, sensation-seeking and risk-taking tendencies are beneficial traits for war fighters (e.g., Momen et al., 2010). Risk-taking has shown to correlate significantly with successful completion of the SOF training (Pleban et al., 1989). Unsurprisingly, sensation-seeking is closely linked with risk-taking (Momen et al., 2010). Risk-taking is inherent to any SOF task and thus, according to Momen et al. (2010), the ideal war fighter is a 'deliberative sensation-seeker' (Momen et al., 2010). Risk-taking was assessed using the revised Domain-Specific Risk Taking (DOSPERT) Scale (Blais and Weber, 2006). This 30-item scale assesses behavioral intentions—or the likelihood that respondents will engage in risky activities—from five areas of life (ethical, financial, health/safety, social, and leisure risks). Higher scores indicate greater risk taking in the subscale area. A second scale of 30 items assesses the perceived degree of risk of each activity/behavior. The combination of both subscales is interesting, especially in this population, to evaluate whether "risky" behavior is indeed perceived as "risky."

Trait anxiety was assessed with the trait scale of the State-Trait Anxiety Inventory (STAI-T; Spielberger et al., 1983). This questionnaire has 20 items including both anxiety-dependent items, e.g., "I am too worried about something that doesn't really matter"; as well as anxiety-independent items, e.g., "I am a stable person." The total score ranges from 20 to 80; the higher the score, the higher the anxiety trait in the individual.

Operators must be able to receive, understand, memorize, and integrate large amounts of complex information (e.g., verbally receive information, procedures, or sophisticated materials) in a short period of time, and in constantly changing settings (e.g., Picano et al., 2017; Farina et al., 2019). Intelligence was evaluated by the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Wechsler, 2008). The ten core subtests are required to calculate the Full-Scale IQ (FSIQ) and the four following indexes: (i) Verbal Comprehension Index (VCI), (ii) Perceptual Reasoning Index (PRI), (iii) Working Memory Index (WMI), and (iv) Processing Speed Index (PSI).

Despite the lack of available literature in military populations regarding emotional intelligence and performance, it has recently gained momentum in sports science (for a review, see Laborde et al., 2016). Emotional intelligence (EI) can be defined as emotional literacy: "the ability to perceive and express emotion, assimilate emotion in thought, understand and reason with emotion, and regulate emotion in the self and others" (Mayer et al., 2000, p. 396; see also Mayer and Salovey, 1997). Layman popularization publications link the concept to motivation, empathy, communication and interpersonal skills (e.g., Goleman, 1995). According to the standard definition, EI consists of four attributes: (i) the ability to perceive, assess, and express emotions quickly, (ii) the ability to recognize and generate the feelings that facilitate thinking, (iii) the ability to understand emotions and knowledge about emotions, (iv) the ability to manage emotions in order to improve emotional and intellectual development (Salovey and Mayer, 1990). Considering the body of research linking this ability to performance in various domains (e.g., Vaughan et al., 2021, linking trait EI to working memory with a growing weight of the relationship with elite status of the athletes), and considering the fact that one of our core assumptions for the current program was to target the team as the basic unit for performance, and thus to have a reliable measure of interpersonal skills related to the quality of the team experience, we included EI in our measurements. Many different EI assessment questionnaires exist, and we decided to choose the one having produced the most research results so far, also being the oldest, being the Bar-On (1997).

Regarding sleep and fatigue, current research also indicates a growing acknowledgment of stable interindividual differences influencing sleep need, vulnerability of performance to sleep loss, and circadian set-up (e.g., Tucker et al., 2007). Two of these clearly identified traits are the sleep need (i.e., normal duration of sleep during one night) and the chronotype (i.e., the circadian preference, as in morningness or eveningness). Regarding the sleep need, a 2-weeks sleep diary has been the easiest method for determining this for decades (Monk et al., 1994). Regarding the chronotype, several questionnaires exist. A recent tool, the Oginska Chronotype Questionnaire (Ogińska, 2011; Oginska et al., 2017) allows for a shorter version mapping both morningness-eveningness, but also diurnal amplitude, that is the range of change in arousal and responsiveness (which has been linked to stress responses) throughout the day. The questionnaire consists of 14 items. Two dimensions of the chronotype are assessed using this questionnaire: the morning-vesperality scale (i.e., the so-called morningness-eveningness, ME; 8 items) and the subjective amplitude scale (i.e., DI; 6 items). The higher the score on the ME-scale, the more it reflects a tendency to be more active in the evening. The subjective amplitude investigates the subjective sense of distinction of daily changes (i.e., the amplitude or range of diurnal fluctuations). The amplitude would reflect the power of the human circadian system (Aschoff and Pohl, 1978). The higher the score on this scale, the stronger the subjective distinction in diurnal variations. Amplitude characteristics appear to be considered an important component of circadian rhythms, particularly in the workplace where it could predict an individual's tolerance to shift work or individual jet lag. Considering the ease of use of this questionnaire, as well as the additional information of amplitude which might be relevant to operators, especially in situations of jet lag, we thus chose this instrument. The different instruments to measure trait variables are summarized in **Table 2**.

Psychometry: State Assessments. The second type of psychometry tools maps state-like variables, likely to vary in different situations, and where the outcome or score might provide an indication regarding the resource use of the individual. Contrary to the trait-like variables, these indicators might be used in a dynamic setting, and be self-managed and monitored by the operators, following the appropriate psychoeducation. Again, our choice was guided by several criteria: (i) the ease of use and interpretation, to be applied without an expert, hence the possibility to fully automate and self-administer the measures and make the operator self-sufficient in its use; (ii) a duration of administration that is short enough to allow for an administration "on the go"; (iii) a well-documented and validated sensitivity to situational variables likely to affect performance in our population. The state questionnaires (i.e., profile of mood scale, state anxiety scale, sleep quality as well as subjective level of mental fatigue, physical fatigue, stress and sleepiness) specifically assessed the psychological state of the participants at different moments in time (baseline measures, during courses and deployments) to provide individuals with a referential framework. **Table 3** provides an overview of these different instruments. The variables chosen were anxiety (Spielberger STAI S-subscale), overall mood state and sleep quality.

Regarding overall mood, the Profile Of Mood States (POMS) has become the most widely used instrument in applied research. The Profile of Mood States (POMS) questionnaire can be a key instrument in reporting the negative and positive mood states changes during exhaustive periods of training in athletes (Meeusen et al., 2013). The 32-items POMS has five subscales: tension-anxiety (POMS-T), depression-dejection (POMS-D), anger-hostility (POMS-A), fatigue-inertia (POMS-F), and vigor-activity (POMS-V). For athletes, the "Iceberg Profile" has been acknowledged as the healthy norm. This is a representation of POMS scores, with scores below population average on the subscales fatigue, depression, tension and anger, and a sky-high "top of the iceberg" score on the subscale vigor. This positive

TABLE 2 | Summary of the psychometry tools used for mapping of the selected trait variables.

Variable	Instrument	Source	Administration duration	Scoring duration
Personality	NEO-PI-R	Costa and McCrae (2008)	50 min	Automated
Anxiety	STAI-T	Spielberger (1983)	7 min	Automated
Hardiness	Lo Bue	Lo Bue (2015)	15 min	Automated
Risk-taking	DOSPERT	Blais and Weber (2006)	20 min	10 min (manual comparison of both subscales needed)
Emotional intelligence	Bar-On EQi	Bar-On (1997)	30 min	Automated
Intelligence	WAIS IV	Wechsler (2008)	2 h	30 min
Chronotype	Ogińska	Ogińska (2011)	7 min	Automated
Sleep need	Sleep diary	Monk et al. (1994)	5 min daily for ∼2 weeks	30 min

The durations to score do not include the initial time investment needed to design a scoring interface.

TABLE 3 | Summary of the psychometry tools used for the psychological mapping of selected state variables to allow for self-monitoring.

Variable	Instrument	Source	Administration duration	Administration frequency	Scoring duration
Anxiety	STAI-S	Spielberger (1983)	7 min	On demand	Automated through an online interface
Fatigue	VAS	Frey (2018)	10 s	On demand	
Sleepiness	VAS	Frey (2018)	10 s	On demand	
Psychomotor response speed	PVT	Dinges and Powell (1985)	10 min	On demand, circadian influence on result	
Sleep quality	PSQI	Buysse et al. (1989)	10 min	Monthly	
Mood	POMS	Curran et al. (1995)	7 min	On demand	

The "on demand" description of administration frequency indicates the possibility for operators to take the measure whenever they deemed appropriate or necessary.

visual profile is typical and very common for well-trained athletes (Vrijkotte et al., 2016). The Iceberg Profile of SF operators and their candidates has already been compared to elite athletes (Johnson et al., 2019).

Experiential sampling is a unique way to gain insight in how a person perceives mood, bodily sensations, feelings, and resource allocation during a given activity. In order to give operators insight in this quantification, we taught them to use Visual Analog Scales to log "Mental Fatigue," "Physical Fatigue," "Sleepiness," and "Stress." The Visual Analog Scale (VAS) we used is a 100 mm horizontal rating scale without numbers, where participants mark a point that indicates the intensity of the subjective phenomenon. The ends are extreme limits of the parameter to be measured, in this case the extremities vary between the limits "not fatigued/stressed/sleepy at all" on the left side and "extremely exhausted/stressed/sleepy" on the right side of the line. The VAS has shown to be a fast and reliable instrument in this population (Vrijkotte et al., 2018).

Regarding sleep, we also included a monthly Pittsburgh Sleep Quality Inventory (PSQI), which has been the clinical gold standard for decades for screening and follow-up of sleep quality (Buysse et al., 1989). The PSQI consists of 21 questions. Each question measures a specific area in which sleep problems might occur. Seven components are assessed; and their associated questions are as follows: Component 1, subjective sleep quality-question 9; Component 2, sleep latency-questions 2 and 5a; Component 3, sleep duration-question 4; Component 4, habitual sleep efficiency-questions 1, 3, and 4; Component 5, sleep disturbances-questions 5b through 5j; Component 6, use of sleep-promoting medications-question 6; Component 7, daytime dysfunction-questions 7 and 8. The formulation of the questions targets variations and state over the last month.

Regarding anxiety, since the original instrument designed by Spielberger specifically differentiated between trait and state anxiety, the "State" subscale was used to include in the situational variables.

Layer 2 = Individual Feedback Based on the Results of the Assessment

The core of this step was the customization. The information collected in "Layer 1" was fed back in individual interviews with the operators. A clinical systemic interview was conducted with each of them by a trained systemic psychotherapist, as well as an interview with a performance psychologist, as well as a joint feedback interview with both. It is unusual in psychology to have both disciplines work closely together, yet this seemed a necessity considering our basic requirements formulated earlier. During these interviews, individual strengths and weaknesses were identified and discussed. Where necessary, further investigations and potential interventions were discussed. An example of such a referral was the identification of a sleep pathology, where the referral to a clinical sleep specialist allowed for the identification of an obstructive sleep apnoea syndrome, which could be surgically treated. Another example of the operational use of this personalized feedback was the choice of team specialty by one of the younger operators, who had initially been directed to the "sharpshooter/sniper" track, but who expressed a wish to change this based on his individual cognitive feedback.

Regarding the clinical interview, as this was constructed as a systemic "intake," it explored personal relationship and family life as well, and if necessary or if the operator expressed the need for it, family interventions were also scheduled. This is in line with one of the objectives stated in the Method section, regarding the support of partner relationship, being one of the coping mechanisms of the operators.

A paramount feature of this stage was the consultation within the project design team, to be able to integrate feedback and interventions from the different areas of expertise (physical training, physiotherapy, medical consultations, and psychological assessments and interviews). Between the interviews and the interventions, each operator's case was discussed within the multidisciplinary team, in order to ensure the full situational awareness of each expert regarding the most appropriate care for this operator.

Furthermore, the steps of the next layer, being the integration in the team, were discussed at this stage within each individual consultation, to allow each individual sufficient time to determine his boundaries regarding individual and team feedback. This also paved the way for this first explicit intervention in team dynamics with experts from "outside" the operators' community. As indicated by our initial survey regarding psychological support (Huret, 2018), which we summarized in the "Methods" section, the trust relationship that had been forged by the repeated participant observations was of paramount importance to obtain buy-in from the individual operators at this stage.

The main message from this layer on was the responsabilisation of the individual, to reach a co-creation of the guidance and support process with the professionals, consistent with the therapeutic assumptions in systemic psychology (Jorgensen, 1989; McTaggart, 1991; McIntyre, 2007; Gergen, 2008; Spradley, 2016).

Layer 3 = Team Feedback and Interventions

As Hollnagel (1998) wrote more than two decades ago: "in the study of human performance the definition or specification of what one should measure is undoubtedly the most important problem, whether for individual or crew performance. Measurements must meet three essential requirements: (i) they must be possible; (ii) they must be reliable; and (iii) they must be meaningful or valid. Very few of the measurements that are used in practice meet all three requirements." This has remained an issue in the field of team performance. We posit that the type of test matters, however, one variable often overlooked when working with assessment results is the quality of the expert who provides the feedback and thus uses the information. In this programme, all psychometry results were discussed, fed back and integrated in team workshop guided by a combination of a trained clinical psychologists, a neuropsychologist, a MD and a performance psychologist.

Regarding personality and team interactions, we based our team feedback and interventions on the NEO-PI-R and the EQi results. Considering the fact that the operators had been exposed to the Myers-Briggs Type Inventory (Myers, 1962) in a former international training, and wished to build further on these notions, we coupled the MBTI typology to the feedback from the NEO-PI-R, based on McCrae and Costa's work in the field McCrae and Costa (1989) and the EQi. This situation actually exemplifies the experience of a lot of psychology professionals with the MBTI. As stated by Stein and Swan (2019), "Despite its immense popularity and impressive longevity, the Myers-Briggs Type Indicator (MBTI) has existed in a parallel universe to social and personality psychology." These authors provide a rigorous analysis on the theoretical assumptions behind the MBTI as well as a review of available evidence confirming/infirming the use of the test. They also explain in detail why it might be counterproductive, given the popularity of the instrument in a general public, to try and convince people of its inherent flaws. They describe a potential pragmatic use of the test, as a kind of "door-opener" to awareness regarding one's own functioning, which, as they state, is what is also advocated by the company selling the instrument. Indeed, as identified by Stein and Swan, "the MBTI is sold not necessarily on its theoretical rigor but on its ability to help its users (Stein and Swan, 2019)." We thus followed these authors pragmatic vision, and actually used the MBTI as a simplifying language transition between other tested dimensions and our feedback.

Considering the small size and very equalitarian structure of the team we were working with, we included a "third-person" assessment rather than a 360° feedback. This encompassed filling in an MBTI as each and every other team members, in order to qualify the difference between self-perception and perception by others. This relates to the concept of social desirability and authenticity, which we deemed worthy of more investigation, considering the importance of team dynamics as a coping mechanism in our initial survey.

Usually, in the context of assessment, social desirability is discussed as a bias threatening the reliability of questionnaires assessment. According to Paulhus (1984), social desirability could be viewed in terms of either self-deception (SD), or impression management (IM). IM is a conscious process in which participants intentionally dissimulate information to create a socially desirable image (Wrangham, 1999). Therefore, Paulhus (1984) recommends controlling IM in personality measures as it may represent a conscious bias (Burns and Christiansen, 2006). In contrast, SD refers to instances when respondents actually believe their positive self-reports (i.e., positive illusions). In non-military contexts, positive illusions appear to enhance performance by deflecting attention from anxiety, pain, and fatigue, both among groups and individuals (Wrangham, 1999). SD reveals to some degree how respondents subconsciously alter their answers to protect their self-esteem (Bobbio and Manganelli, 2011). Knowing the importance of positive self-esteem to effectively cope with worksite adversity in any demanding situation (Folkman and Moskowitz, 2004), SD may also underlie success in military context (Wrangham, 1999). Since the success of this team intervention was based on the willingness to share authentically, we included social desirability in the assessment, in order to make participants aware of their dispositions regarding this aspect of their behavior. The social desirability was measured using the Balanced Inventory of Desirable Responding (BIDR; Paulhus, 1984, 1991). The BIDR includes 40 statements and scores can range from 20 to 140, with the highest scores reflecting the highest levels of either self-deception or impression management.

As mutual trust among team members is consistently cited by operators as one of the core features of the "SOF mindset," we targeted this dimension as the cornerstone of the team intervention in a systemic framework. Indeed, coupling the results of individual feedbacks (from the NEO-PI-R, the EQi, and the MBTI) to the results of the "third-person" assessments and the BIDR test results allowed for a workshop covering authenticity and differences in interpersonal functioning. Each team member identifyed defining features of his team mates, as well as differences and common denominators in their individual functioning regarding personal preferences in problem solving, decision making and communication. This took place over the course of 1 week, in three sessions lasting each for 3 h, in order to allow for a sufficient maturation of the information and the feedback, to ensure a common mental model of the team dynamics as the end goal. The evolution of team dynamics over the course of these three sessions was noteworthy, as it served the team reinforcing purpose. The team started as a recipient of experts' feedback during the first session, to move to autonomous communication handling the vocabulary of teamwork, communication, and collaborative decision making in the last session. In this way individual feedback moments of individual experts were exchanged on a team level in function of the team and these team dynamics nurtured the individual motivation and performance goals. This was the foundation for the implementation of the team training, which we describe in the next section.

Step 4: Implementation in a Pilot Project: A One-Year Follow-Up of One SOF Team

The Multidisciplinarity of the Team Training

In order to fulfill one of our core objectives, being a holistic multidisciplinary approach, the specialists' program had to be woven together, in a way where each professional would understand and buy-in to the interventions from the other, and identify potential synergies. This required several coordination meetings, and the opportunity for each specialist to learn about the assessment and interventions of the other fields. The coordination meetings were also the opportunity to schedule our pilot project implementation. Considering the high operational tempo for operators, a modular approach of 4 weeks over 1 year was chosen, which would be completed with *ad-hoc* interventions on deployment, either with an expert deployed as part of the team, or with a reach back capacity.

Prior to the start of this follow-up, each specialist educated the other team members regarding his/her approach (i.e., the content of the previous sections of this paper), explaining the "what," the "why," and the "how" of the individual assessment, feedback and interventions. Furthermore, during each of the 4 weeks, all the experts freed their schedule to be completely available, and whenever possible to partake in all the activities of the program. This served a 2-fold purpose: on the one hand it ensured an in-depth knowledge and understanding of the full program in order to identify all the possible synergies and leverages to better coach the operators in each domain; on the other hand, it demonstrated the practical implication of each expert to the participating operators, thereby demonstrating that the co-creation of this program was not a hollow buzzword, but a practical reality. The sum of the preparatory work and the availability during those weeks meant a significant additional workload for the involved experts, but also a hugely rewarding experience.

One component of the program which we have not described yet, but which was essential to ensure the eventual autonomy of the team, and the impact of the feedback in the different areas, is an educational component. In the SOF community, the need for training operators on the weapon systems they use would never be questioned, however there are virtually no resources devoted to educating operators in the function of their own weapon system—their brain and body. Practical training in weapons and tactics (for example) involve theoretical and practical applications leading up to real time, full mission profile activities. We chose this same approach to a basic introduction in how humans work as a system, on the individual and team level. The summarized content of this training is described in the following section. The different layers of the previously described areas of expertise are woven together in an integrative modular approach, where we start with individual assessments and education and work up toward team autonomy.

From Individual to Team Training: How to Make the Whole Greater Than the Sum of the Parts

Section Layer 3 = Team Feedback and Interventions "Team feedback and interventions" already provided a first glimpse in the process of transfer between the individual assessment, feedback and interventions, and the team level. This was a process that was new for both many of the involved experts and for the operators. Indeed, in the respective areas of clinical medicine, physiotherapy, physical training, and performance psychology, the focus is always on the individual organism: its strengths, weaknesses, and the customization of the necessary interventions for that particular person. The only expert used to work with "networks" of individuals was the systemic psychotherapist. However, one of the basic tenets of our program design was to overcome the duality between individual and team training. Traditionally, operators are selected and trained to aim to be the best. Hence, moving away from this purely individualistic perspective of performance management, while keeping personal standards at a level of excellence was a shift that required some mindset adjustment, moving away from a maximized development of individuals to a balanced development to maximize team performance.

This adjustment was the product of the whole process of this training, however, three interventions explicitly targeted this effect. The first one was an illustrated analogy between the memoir of Chris Hadfield on his career as an astronaut (Hadfield, 2015) and the career of an operator. Hadfield very clearly describes the shift in his mindset between being a competitive, individualistic fighter pilot to being a crew member from a space crew, realizing that his survival chances in space and his possibility to attain execellence depended on the quality of crew performance rather than on his own. Hadfield uses the phrases "how to be a zero" to characterize this mindset shift: how he moved away from trying to be the noticeable best in any system he was involved in, to trying to be a most fluid and efficient cog in an extremely complex machine. The second one was the team intervention described earlier, where team members received and discussed feedback regarding personality assessments and team functioning, during a workshop targeting trust in the team. The third one was a classroom workshop examining real cases of performance assessment and human error in previous courses and deployments, based on our participant observations. These included performance scores for physical or tactical challenges in courses, or elements from after action reviews from deployments. This stage allowed to demonstrate that individuals that might have seemed like "high performers" were actually depending on the system (team, unit) in which they functioned in order to deliver real-life high performance. All these interventions are summarized in the "Implementation blueprint" section further on. As the team was a pivotal element in this aspect of the process, the fact that they further applied these notions in team activities outside our human performance program was paramount to its success, and was to us a clear indicator of the adequacy of the chosen approach.

For the expert team, the process was guided by the theoretical framework of system theory. As stated in the Method, our program design was a non-hierarchical co-creation between the experts and the actual client, and in this particular stage, the focus was intentionally slowly shifted from the individual client to the team as client. This took place over the course of the 1-year follow-up, with a strong shift as of the second week of the program, where all the individual assessment and feedback had taken place during the first week, and where this second week saw the emergence of "the team" as the client, rather than each individual.

Implementation Blueprint: The Kitchen Recipe

We thus conceived the program as a modular build-up around six periods throughout the year: 4 weeks at the unit, hence neither deployed nor in training; and two deployment periods. The four weeks at the unit are the only ones throughout a whole year where a team is together in a "normal" work environment, they are called the "administration and logistics" weeks. The fact that there are only four of those weeks in a year underscores the operational pressure we have mentioned throughout the current paper. The two deployment periods were one mountain training of 3 weeks, where the PTI was the embedded expert; and one operational deployment of 3 months, where the MD was the embedded expert for 1 month. The content was built starting from individual assessment and education to feedback and insight, allowing for practical workshops empowering autonomy and targeted intervention in function of needs. As mentioned before, the focus shifted from the individual to the team as soon as the second week. **Table 4** provides an overview of the schedule and organization for the team members (hence not taking into account the preparatory work and coordination between the experts). As the year went by, the process evolved from an expert-giving-counsel model to a true co-development with the team, based on the developing insights and experience.

Lessons Learned

We will only summarize here the main take home messages, which readily translate to team sports as well as to the SOF environment.

Involvement of Experts: WYGIWYG (What You Get Is What You Give)

The main challenge for the involved experts was the availability requirements: the fact that they had to be reachable almost 24/7, extremely flexible regarding timing, and very creative to combine this support function with other job requirements (as none of the involved experts was dedicated to this target population). Indeed, the scheduled weeks for interventions changed several times, and the availability of the operators was extremely volatile (which is not surprising, considering the fact that these were the only weeks of the year where they were actually in country and without training requirements). The main positive outcome was to work with enthusiastic and highly motivated people, who adhered to the program and made it their own in a couple of months, showing rapid progress in the invested dimensions. The experts thus had to show a disposition of humility, to be willing to learn from colleagues and operators, and make themselves available. The job satisfaction, in return, was proportional to the requested investment.

Outcome for the Team

The main positive outcome for the team was the increased quality of the team processes, insights and self-knowledge, which made them feel stronger by having clearly identified strengths and weaknesses and the leverage points to address those. The mutual transfer of knowledge between the individual interventions, team workshops and classroom sessions to real-life situations showed a successful implementation of the selected concepts. However, they also reported a high level of frustration with feeling a "culture clash" in the unit, with obstacles to putting their new knowledge into practice (e.g., scheduling or food purchases). They thus emphasized the need, for such a program to actually be effective, to be implemented at every level of management and decision making. Considering the described psychological profile of operators in terms of overachievement, it is not surprising that, if they adhere to the programme, they would feel frustrated at being hindered from applying it in the most complete and efficient way. This issue further validates our initial systemic approach, however, functioning in an organization the size of Defense, it is impossible to decentralize some decision processes. This might be easier in a sports team environment.

Ethical Consideration: Care and Confidentiality

Both experts and operators emphasized the importance of one of our basic cornerstones, being the confidentiality of the process. The fact that none of the assessment results (clinical, physical or mental) were part of their official record; and the fact that

TABLE 4 | Implementation blueprint.

Administration and logistics weeks			
BLOCK 1	1 week (Jan)	Education (team classroom sessions)	1. Introduction to the program and goalsetting (1 h) 2. Exercise physiology and training principles (4 h) 3. Information processing and learning processes (4 h)
		Individual assessment	1. Initial medical interview 2. Psychometry tools 3. Individual intake interview with the clinical psychologist 4. VO2 max testing at the sports physiology laboratory 5. Individual physiotherapy screening: questionnaire and consultations
		Team intervention	First team training session with PTI to illustrate training principles (half day)
BLOCK 2	1 week (Apr)	Education (team classroom sessions)	1. Nutrition basics (4 hrs) 2. Communication and team cognition (2 h) 3. Sleep and fatigue management for optimal performance (2 hrs)
		Individual assessments	1. Full physical assessment with PTI 2. Repeat sleep aspects of psychometry
		Individual intervention/Feedback	Individual consultation with physiotherapist and PTI to discuss customized training program based on the assessments of block 1.
		Workshop/Practical exercise	1. Nutrition: analysis of the different types of field rations used by the unit 2. Exercise on determination of metabolic needs in function of different types of settings and activities (based on real exercises/deployments) 3. Sleep and fatigue: scheduling examples based on observational data from the mission of the previous year
		Feedback	Individual interview with the psychologists regarding the psychometry results from block 1.
		Team intervention	1. Introducing the concept of team performance management and the team assessments 2. Group workshops around personality types, behavioral preferences, and team dynamics
BLOCK 3	1 week (Jun)	Individual intervention	1. Individual follow-up with physiotherapist and PTI on customized training program 2. Individual pre-deployment interview with clinical psychologist
		Team intervention/workshop	1. How to implement the Human Performance Program on deployment. 2. Team cognition, performance, and human error: how to reframe error analyses (with real-cases examples). 3. Team training session with PTI
BLOCK 4	1 week (Dec)	Individual assessment	Repeat of the full physical assessment to evaluate impact of deployment.
		Individual intervention	Follow-up with physiotherapist and PTI on customized training program. Follow-up consultation with ad hoc experts based on individual needs.
		Team intervention/ workshop	1. Debriefing on human performance aspects on deployment: physical activity, nutrition, sleep and fatigue. 2. Education refresher regarding nutrition and sleep (2 x 2 hrs) based on feedback during deployment.
Deployment periods			
Mountain training period	3 weeks (Feb)	Mixed education/intervention with PTI: 1. Injury prevention and recovery applied to a technical and tactical setting. 2. Physical activity as a means (technical), an end (tactical), and a recovery resource (mountaineering activity during the free week-end). 3. Emphasis on the importance of managing physiological resource spending and acceptable pain thresholds depending on the context. 4. Illustration of nutrition choices depending on the type of activity.	
Operational deployment	3 months (Aug-Nov)	Interventions: 1. Managing nutrition in a resource-constrained environment, based on the previous lectures and workshops. 2. Adapting sustained operations schedule to the team set-up in terms of chronotype and sleep need; 3. Individual physical training schedules depending on available time and space. Availability of the experts (PTI, MD, Physiotherapists, Psychologists) for reach back guidance and support.	

Overview of the integration of the specialists' approaches described in the previous sections at the scale of one team (8 operators).

they had the assurance that their results were actually their property were paramount to the success of this pilot project. In order to work on one's own functioning, it is an absolute necessity to face one's limitations, failures and weaknesses. However, in an evaluation context (e.g., regarding professional fitness qualifications, or in a sports team, regarding player trading decision making), there is no room for such openness, no room for individuals to lay open their vulnerabilities. This determines the mutual trust relationship, the absolute honesty in assessment situations (for both clinical interviews and questionnaires); and the overall feeling that the programme was an alliance between professional experts and operators to provide operators with the best possible support both on an individual and team level, which is the definition of a therapeutic alliance (e.g., Gergen, 2008). The fact that many performance management programmes in the sports world are designed or managed without this clinical background and care deontology in mind is a point of attention, as this seemed essential in the success of the endeavor. It is noteworthy that the management within both the operational unit and the military medical service never questioned this position, and never attempted to overrule it. This underscores the humanistic approach of the Belgian Defense regarding performance management in its personnel.

DISCUSSION

Recent developments in team training show a tendency to leave the reductionist model of "just" training every individual of the team to the maximal capacity. Rather, the team is seen as an adaptive system. The approach differs in a sense that athletes/SOF operators become part of dynamic and complex systems, thus requiring a systemic and holistic approach. In 2016, Soltanzadeh and Mooney explored systems thinking and its potential for modeling and analyzing sports team performance, underlining that, to understand the individual parts of a team, we should approach the whole and vice versa. In the current HPP program, we wanted to go one step further. To understand the perspective of every team member on this intersection between individual and team, we used a participant observation approach in order to gain information from their expertise and to preserve a co-creation between the team, the individuals and the program developers (Jorgensen, 1989; McTaggart, 1991; McIntyre, 2007; Gergen, 2008; Spradley, 2016). By applying this systemic approach, we aimed at designing a human performance program that could serve both the individual and group level of the team. As Bateson emphasized, to understand human communication and team play, we must go further than the systemic thinking of thermodynamic laws that reduce dynamic relationships to linear causality: "In this strict sense, the impact of one billiard ball upon another is subject matter for dynamics, but it would be an error of language to say that billiards balls "behave".... we, however, are not concerned with event sequences which have this characteristic" (Bateson, 1972). We thus set out to design a human performance program aimed at overcoming the dichotomy between mental and physical performance; between care for existing injuries and performance optimization; and between individual training and team functioning.

The current paper presents its first practical application within a SOF team. First things required are a current status report and a needs assessment. A current status report is obtained based on relevant, valid and reproducible test procedures. This required key physiological and psychological parameters to be identified, in order to have tracking variables. The needs assessment required consultation, participant observation and multidisciplinary analysis, making it possibly the most labor-intensive part of the program design. The combination of that current status report; the identification of the key components to measure; and the result of the needs assessment provided us with several leads for leverage. These leads were: (i) to adopt a holistic and systemic approach; (ii) to capitalize on strength by tailoring to the level of the individual operator and support constructive coping mechanisms (recreational sports; team dynamics and partner relationships); (iii) to address the main vulnerability, being musculoskeletal injuries; (iv) to identify the necessary improvements in nutrition and sleep management.

This approach allowed us to create tailor-made training programs and provide substantiated feedback at an individual and team level. Customized training programs also bring along the advantage of being more focused, and therefore more time-efficient compared to general training programs. Within a SOF-context, time-efficiency is paramount, as operators are abroad most of the year for operational missions or technical exercises, which clearly showed in our implementation project. This is also the reason why we chose, right from the start, to develop the autonomy of operators through education and the empowerment to reach a level of self-management, with a reach back guidance of experts available. The status reports further provide the opportunity to follow-up over time. Data that are gathered on a regular basis throughout the years will allow for a more and more accurate monitoring of both the individual and the group performance level. The third and final step in our approach was the integration of the individual in the team, and to let the team evolve into a strong and competent unit, with a specific set of skills well-aligned between the members of the team. This was achieved through team training, firstly for a physical dimension, then with an educational approach, then a coaching toward autonomy in the analysis of team processes in real-life exercises and deployments. The insight brought within the team was defined by the pilot project SOF team as the most important positive outcome to the program, supporting their efficiency and allowing them insight in their own functioning, eventually empowering them to leverage more tools to support their performance.

A limitation to our holistic approach is the lack of a spiritual component. Other human performance optimization programs (e.g., Chamberlin et al., 2020) specifically address this dimension in the performance optimization approach. We deliberately left it out because of its cultural sensitivity in Belgium, where our recent history is still marked by tensions between organizations acknowledging a religious affiliations and others claiming a complete separation between state and church. Despite the fact that the Belgian Defense has a humanistic and inclusive view of pastoral care, tending to several religions and non-religious moral care, we chose to pick our battles, and start with a program where the content of the expertise would not be a matter of debate. Furthermore, whereas we believe this matter to be of utmost importance for personnel confronted with life and death decisions, it might be less relevant in the transfer to the sports science environment.

An important limitation of the current paper is that it misses the final stage of Intervention Mapping, being program evaluation. There are several reasons for that. Firstly, the program objectives were defined according to needs, not according to measurable variables. Whereas, this may be seen as a weakness from a design management point of view, we see it as a strength from an ecological validity point of view: we set out to provide support regarding actual needs of the client, not regarding program design and evaluation. The objectives we thus defined do not fit an evaluation in the usual timeline of a research and development project, for these variables have a different time resolution: injury reduction, for example, takes several years to show in prevalence numbers, especially considering the chronic feature of the diagnosed injuries in the musculoskeletal assessment. It might need a complete new generation of operators, where this performance management approach is applied right from the start, to actually show a measurable benefit in prevalence. Secondly, since one of the fundamental choices in the design and implementation of this program was to advocate first and foremost for the interests of the individual operator, it is difficult to identify in this multidisciplinary framework objective, reliable and valid variables that would represent the effect of the program as a whole. As Cameron wrote in 1963: "It would be nice if all of the data which sociologists require could be enumerated because then we could run them through IBM machines and draw charts as the economists do. However, not everything that can be counted counts, and not everything that counts can be counted." Thirdly, our aim in the current paper is to provide a detailed description of the applied method, a "kitchen recipe" to disseminate the work from the program design as such, and the rationale behind the methodological choices.

A specificity of the current paper, which can be seen as both a strength and a limitation, is that we aimed to span the whole resolution spectrum of our program design: from conceptual and management choices to workshop floor details. We believe it shows the highest level of transparency in the process, despite being unorthodox for a scientific paper. The level of detail in the assessment and intervention description is kept to ensure the usefulness of the content to practicing professionals. The resolution adjustment this demands from the reader may hamper a smooth reading, and definitely do not make for an elegantly parsimonious structure, like we normally favor in scientific papers. Yet we are grateful for this opportunity to prove Richard Feynman wrong, who addressed this issue in his Nobel prize recipient address in 1966: "We have a habit of writing articles in scientific journals to make the work as finished as possible, to cover up all the tracks, to not worry about the blind alleys or describe how you had the wrong idea first, and so on. So there isn't any place to publish, in a dignified manner, what you actually did in order to get to do the work."

In the approach described here, multidisciplinarity is a cornerstone of the program we designed, and definitely one of its major strengths. However, one of the lessons learned from this implementation is the "hidden cost" of multidisciplinarity in terms of workload. Multidisciplinarity is only supporting a holistic approach if every professional involved is willing to step out of his comfort zone to actively look for overlaps with the other areas of expertise. This requires communication; and time to learn: time to attend screenings and trainings from the other professionals, time for joint consultations with athletes/operators, time for self-education and research. As every manager will tell: time is money. However, the creativity, drive and achievement that was experienced by every professional involved allowed to reach the goal of designing the program in a quite tight timeframe, being 30 months from the "start from scratch" at the whiteboard to the end of the pilot project implementation in real life.

This issue of the cost of multidisciplinarity and the question of program evaluation actually tie in to a third question, which will be common to military and sports settings: how can the return on investment of such an approach be demonstrated? This issue is becoming more timely than ever: in the aftermath of the Tokyo Olympics in 2021, French president Macron famously "welcomed" the French Olympic team back with an address mentioning what he called the lack of results compared to the amount of public spending in sports (Métairie, 2021). This question of return on investment raises again the dilemma regarding what counts, and can be counted.

Return on investment brings us back to one of our basic design choices regarding the program. We set out in the framework of a care work ethic, to care for our patient/client, at the level of the individual operator/team. Regarding the translation to team sports, the same choice has to be made: does an intervention target the interests of the athlete, or the interests of the management? Considering the typical need for achievement of athletes (and operators!), these are aligned in a nominal situation, where everybody agrees on the end goal: to perform as successfully as achievable, and to bring the unachievable within reach. However, as emphasized by Malgoyre et al. (2015) in their article regarding performance enhancement in elite athletes and soldiers, at some point, the short and long-term interests of the individual and the organization may diverge regarding cost-benefit analysis of interventions. As we already discussed in the introduction: maximal performance does not equal optimal health, and many performance-enhancing choices of both elite athletes and elite soldiers may damage their long-term health and well-being. This is a conundrum to which we cannot suggest an answer, yet an issue that must remain open to discussion.

Despite the specific nature of a SOF team, as we discussed throughout the present paper, the approach described here can readily be transposed to elite team sports training. Sport scientists and practitioners will surely benefit from a further integration of dynamic constructs such as cohesion, leadership and collective efficacy, summarized as team togetherness, combined with the team's intrinsic value at the individual level (Bourbousson et al., 2019). Similarly to a SOF team, designing periodized training programs for team sports athletes poses unique challenges and difficulties. Nevertheless, Mujika et al. (2018) recently stressed that both physical and strategic periodization are useful tools for managing the heavy travel schedule, fatigue, and injuries that occur throughout a competitive season/career. Despite the different types of challenges, the result is similar for SOF teams and elite sports teams. In addition, Mujika et al. (2018), like in the current paper, put forward that psychological skills are a central component of athletic performance, and their periodization should cater to each athlete's individual needs and the needs of the team. The similar topics that have been focussed on in the current paper and in the publication of Mujika et al. (2018) stress the usefulness of comparing performance optimization programs in both fields of application (i.e., the SOF context and the team sports context) and underline that this can be crucial in order to further advance this field of research. Adopting a holistic approach in a team sports context will, like in a SOF context, allow to make more of each supporting professional's capacities, to fully utilize the team around the team. The implementation constraints in terms of cost and availability of experts are quite similar too. And contrary to the SOF setting, the team sports setting combines two features which allow for easier implementation. Firstly, there is the performance timeframe, around seasons, that could make an evaluation easier against objective external criteria. Secondly, the smaller scale of decision making levels around a sports team could make implementation faster and more efficient.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board, UZ Brussel. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

NP, ED, MH, MS, RV, JV, JP, EN, ND, and DV participated in every stage of the program design and implementation. JV, BR, AC, GR, EL, VT, and MV provided expert knowledge back-up on the program design and regarding the manuscript redaction. NP, JV, BR, GR, EL, MV, EN, ND, and DV contributed to the manuscript. All authors reviewed and commented on the manuscript and its final version has been approved by all.

FUNDING

This research was funded by grant HFM 17-05 from the Belgian Defense.

ACKNOWLEDGMENTS

The authors wish to thank the community of operators for their relentless commitment to excellence. The authors also wish to acknowledge the useful reviews of two reviewers, who significantly contributed to improving the manuscript.

REFERENCES

Abt, J. P., Oliver, J. M., Nagai, T., Sell, T. C., Lovalekar, M. T., Beals, K., et al. (2016). Block-periodized training improves physiologically and tactically relevant performance in naval special warfare operators. *J. Strength. Cond. Res.* 30, 39–52. doi: 10.1519/JSC.0000000000001082

Aschoff, J., and Pohl, H. (1978). Phase relations between a circadian rhythm and its zeitgeber within the range of entrainment. *Naturwissenschaften*. 65, 80–4. doi: 10.1007/BF00440545

Barber, S. D., Noyes, F. R., Mangine, R. E., McCloskey, J. W., and Hartman, W. (1990). Quantitative assessment of functional limitations in normal and anterior cruciate ligament-deficient knees. *Clin. Orthop. Relat. Res*. 255, 204–214. doi: 10.1097/00003086-199006000-00028

Bar-On, R. (1997). *The Emotional Intelligence Inventory (EQ–i): Technical Manual*. Toronto, ON: Multi-Health Systems.

Barry, D. M., and DeVries, M. (2019). Performance enhancement assessment and coaching in US army special operations: rapidly enhancing performance through targeted, tailored feedback. *J. Spec. Oper. Med*. 19, 66–73.

Bartholomew Eldridge, L. K., Markham, C. M., Ruiter, R. A. C., Fernàndez, M. E., Kok, G., and Parcel, G. S. (2016). *Planning Health Promotion Programs: An Intervention Mapping Approach (4th ed.)*. Hoboken NJ: Wiley.

Bartone, P. T. (1999). Hardiness protects against war-related stress in army reserve forces. *Consult. Psychol. J. Pract. Res*. 51, 72–82. doi: 10.1037/1061-4087.51.2.72

Bartone, P. T., Roland, R. R., Picano, J. J., and Williams, T. J. (2008). Psychological hardiness predicts success in US Army Special Forces Candidates. *Int. J. Select. Assess.* 16, 78–81. doi: 10.1111/j.1468-2389.2008.00412.x

Bateson, G. (1972). *Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, And Epistemology*. Northvale, NJ: Jason Aronson, Inc.

Blais, A.-R., and Weber, E. U. (2006). A Domain-Specific Risk-Taking (DOSPERT) scale for adult populations. *Judgm. Decis. Mak.* 1, 33–47. doi: 10.1037/t13084-000

Blanpied, P. R., Gross, A. R., Elliott, J. M., Devaney, L. L., Clewley, D., Walton, D. L., et al. (2017). Neck pain: revision 2017. *J. Orthop. Sports Phys. Ther*. 47, A1–A83. doi: 10.2519/jospt.2017.0302

Bobbio, A., and Manganelli, A. M. (2011). Measuring social desirability responding. a short version of Paulhus' BIDR 6. TPM-Testing. *Psychomet. Methodol. Appl. Psychol.* 18, 117–135.

Bourbousson, J., Feigean, M., Seiler, R. (2019). Team cognition in sport: how current insights into how teamwork is achieved in naturalistic settings can lead to simulation studies. *Front. Psychol*. 10, 2082. doi: 10.3389/fpsyg.2019.02082

Bressel, E., Yonker, J. C., Kras, J., and Heath, E. M. (2007). Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. *J. Athl. Train.* 42, 42–46.

Burns, G. N., and Christiansen, N. D. (2006). "Sensitive or senseless: On the use of social desirability measures in selection and assessment," in *A Closer*

Examination of Applicant Faking Behavior, eds A. Griffith and W. Peterson (Charlotte, NC: Information Age Publishing). p. 390.

Buysse, D. J., Reynolds, C. F. 3rd, Monk, T. H., Berman, S. R., and Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 28, 193–213. doi: 10.1016/0165-1781(89)90047-4

Caldwell, J. A., and Caldwell, J. L. (2005). Fatigue in military aviation: An overview of U.S, military-approved pharmacological countermeasures. *Aviat. Space Enivorn. Med*. 76, C39–C51.

Carlson, M. J., and Jaenen, S. P. (2012). The development of a preselection physical fitness training program for Canadian Special Operations Regiment applicants. *J. Strength. Cond. Res*. 26(Suppl. 2), S2–S14. doi: 10.1519/JSC.0b013e31825d7ff9

Chamberlin, R. A., Lunasco, T., and Deuster, P. A. (2020). Optimizing special operations forces operator talents and mission capabilities: human performance optimization and total force fitness capability-based blueprint and targeting system. *J. Spec. Oper. Med.* 20, 113–119.

Christensen, P. A., Jacobsen, O., Thorlund, J. B., Madsen, T., Møller, C., Jensen, C., et al. (2008). Changes in maximum muscle strength and rapid muscle force characteristics after long-term special support and reconnaissance missions: a preliminary report. *Mil. Med.* 173, 889–894. doi: 10.7205/MILMED.173.9.889

Christopher, S. M., McCullough, J., Snodgrass, S. J., and Cook, C. (2019). Do alterations in muscle strength, flexibility, range of motion, and alignment predict lower extremity injury in runners: a systematic review. *Arch. Physiother.* 9:2. doi: 10.1186/s40945-019-0054-7

Cole, R. E., Bukhari, A. S., Champagne, C. M., McGraw, S. M., Hatch, A. M., and Montain, S. J. (2018). Performance nutrition dining facility intervention improves special operations soldiers; diet quality and meal satisfaction. *J. Nutr. Educ. Behav.* 50, 993–1004. doi: 10.1016/j.jneb.2018.06.011

Comerford, M., and Mottram, S. (2019). *Kinetic Control Revised Edition: The Management of Uncontrolled Movement*, 1st Edn. (Elsevier).

Costa, P. T., Jr., and McCrae, R. R. (2008). "The revised NEO personality inventory (NEO-PI-R)," in *The Sage Handbook of Personality Theory and Assessment Personality Measurement and Testing, Vol. 2*, eds G. J. Boyle, G. Matthews, and D. H. Saklofske (Thousand Oaks, CA: Sage Publications, Inc), 179–198. doi: 10.4135/9781849200479.n9

Curran, S. L., Andrykowski, M. A., and Studts, J. L. (1995). Short form of the profile of mood states (POMS-SF): Psychometric information. *Psychol. Assess*. 7, 80–83. doi: 10.1037/1040-3590.7.1.80

Day, D. M., and Horn, B. (2010). Canadian special operations command: the maturation of a national capability. *Canad. Milit. J.* 10, 69–74.

Deuster, P. A., Kemmer, T., Tubbs, L., Zeno, S., and Minnick, C. (2017). *The Special Operations Forces Nutrition Guide*. Kindle edition, US Department of Defense.

Dinges, D. F., and Powell, J. W. (1985). Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. *Behav. Res. Methods Inst. Comp*. 17, 652–655. doi: 10.3758/BF03200977

Dolbeer, J., Mason, J., Morris, J., Crowell, M., and Goss, D. (2017). Inter-rater reliability of the selective functional movement assessment (SFMA) by SFMA certified physical therapists with similar clinical and rating experience. *Int. J. Sports Phys. Ther.* 12, 752–763. doi: 10.26603/ijspt20170752

Eisinger, G.C., Wittels, P., Enne, R., Zeilinger, M., Rausch, W., Holzl, T., et al. (2009). "Evidenced-based job analysis and methodology to determine physical requirements of special military occupations," in *Optimizing Operational Physical Fitness*. NATO Technical Report, 1–64.

Falla, D. L., Jull, G. A., and Hodges, P. W. (2004). Patients with neck pain demonstrate reduced electromyographic activity of the deep cervical flexor muscles during performance of the craniocervical flexion test. *Spine* 29, 2108–2114. doi: 10.1097/01.brs.0000141170.89317.0e

Farina, E. K., Thompson, L. A., Knapik, J. J., Pasiakos, S. M., McClung, J. P., and Lieberman, H. R. (2019). Physical performance, demographic, psychological, and physiological predictors of success in the U.S. Army Special Forces Assessment and Selection course. *Physiol. Behav*. 210, 112647. doi: 10.1016/j.physbeh.2019.112647

Fauntroy, V., Fyock, M., Hansen-Honeycutt, J., Nolton, E., and Ambegaonkar, J. P. (2019). Using the selective functional movement assessment for the evaluation of Dancers' functional limitations and dysfunctions: a critically appraised topic. *J. Sport Rehabil.* 28, 891–896. doi: 10.1123/jsr.2018-0054

Folkman, S., and Moskowitz, J. T. (2004). Coping: Pitfalls and promise. *Annu. Rev. Psychol*. 55, 745–774. doi: 10.1146/annurev.psych.55.090902.141456

Franklyn-Miller, A., Bilzon, J., Wilson, C., and McCrory, P. (2014). Can RSScan footscan(®) D3D™ software predict injury in a military population following plantar pressure assessment? A prospective cohort study. *Foot* 24, 6–10. doi: 10.1016/j.foot.2013.11.002

Frey, B. B. (2018). "Visual analog scales," in *The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation*, ed B. B. Frey (Thousand Oaks, CA: Sage Publications, Inc). doi: 10.4135/9781506326139

Frueh, B. C., Madan, A., Fowler, J. C., Stomberg, S., Bradshaw, M., Kelly, K., et al. (2020). "Operator syndrome": a unique constellation of medical and behavioral health-care needs of military special operation forces. *Int. J. Psychiatry Med.* 55, 281–295. doi: 10.1177/0091217420906659

Fulton, J., Wright, K., Kelly, M., Zebrosky, B., Zanis, M., Drvol, C., et al. (2014). Injury risk is altered by previous injury: a systematic review of the literature and presentation of causative neuromuscular factors. *Int. J. Sports Phys. Ther.* 9, 583–595.

Gamble, P. (2006). Periodization of training for team sports athletes. *Strength Condition. J.* 28, 56–66. doi: 10.1519/1533-4295

Gergen, K. J. (2008). Therapeutic challenges of multi-being. *J. Fam. Ther*. 30, 335-3500163-4445. doi: 10.1111/j.1467-6427.2008.00447.x

Gergen, K. J., and Gergen, M. M. (2008). "Social construction and research as action," in *The Sage Handbook of Action Research: Participative Inquiry and Practice* (Thousand Oaks, CA: Sage Publications), 159–171. doi: 10.4135/9781848607934.n16

Glaws, K. R., Juneau, C. M., Becker, L. C., Di Stasi, S. L., and Hewett, T. E. (2014). Intra- and inter-rater reliability of the selective functional movement assessment (sfma). *Int. J. Sports Phys. Ther.* 9, 195–207.

Goleman, D. (1995). *Emotional Intelligence*. New York, NY: Bantam Books, Inc.

Goshtigian, G. R., and Swanson, B. T. (2016). Using the selective functional movement assessment and regional interdependence theory to guide treatment of an athlete with back pain: a case report. *Int. J. Sports Phys. Ther*. 11, 575–595.

Gribble, P. A., and Hertel, J. (2003). Considerations for normalizing measures of the star excursion balance test. *Meas. Phys. Educ. Exerc. Sci.* 7, 89–100. doi: 10.1207/S15327841MPEE0702_3

Hadfield, C. (2015). *An Astronaut's Guide to Life on Earth*. MacMillan.

Hanton, S., Neil, R., and Evans, L. (2013). Hardiness and anxiety interpretation: an investigation into coping usage and effectiveness. *Europ. J. Sport Sci.* 13, 96–104. doi: 10.1080/17461391.2011.635810

Helgadottir, H., Kristjansson, E., Mottram, S., Karduna, A., and Jonsson, H., Jr. (2010). Altered scapular orientation during arm elevation in patients with insidious onset neck pain and whiplash-associated disorder. *J. Orthop. Sports Phys. Ther.* 40, 784–791. doi: 10.2519/jospt.2010.3405

Herman, G., Nakdimon, O., Levinger, P., and Springer, S. (2016). Agreement of an evaluation of the forward-step-down test by a broad cohort of clinicians with that of an expert panel. *J. Sport Rehabil.* 25, 227–232. doi: 10.1123/jsr.2014-0319

Hildebrandt, V. H., Bongers, P. M., van Dijk, F. J. H., Kemper, H. C. G., and Dul, J. (2001). Dutch Musculoskeletal Questionnaire: description and basic qualities. *Ergonomics* 44, 1038–1055. doi: 10.1080/00140130110087437

Hollnagel, E. (1998). "Measurements and models, models and measurements: you can't have one without the other," in *NATO RTO Meeting Proceedings 4, Collaborative Crew Performance in Complex Operational Systems*. Edinburgh.

Huret, M. (2018). Analyse des besoins psychologiques des Forces Spéciales pour une optimisation de leur opérationnalité. Quel appui psychologique peut-on proposer aux opérateurs ? Thèse de Formation Candidat Officier Supérieur ; 43ème session. Defence College, Brussels, Belgium.

Hystad, S. W., Eid, J., Johnsen, B. H., Laberg, J. C., and Bartone, P. T. (2010). Psychometric properties of the revised Norwegian dispositional resilience (hardiness) scale. *Scand. J. Psychol.* 51, 237–245. doi: 10.1111/j.1467-9450.2009.00759.x

Impellizzeri, F. M., Marcora, S. M., and Coutts, A. J. (2019). Internal and external training load: 15 years on. *Int. J. Sports Physiol. Perform.* 14, 1–4. doi: 10.1123/ijspp.2018-0935

Johnson, C. D., Nijst, B. K. J. F., Eagle, S. R., et al. (2019). Evaluation of shoulder strength and kinematics as risk factors for shoulder injury in United States special forces personnel. *Orthop. J. Sports Med.* 7:2325967119831272. doi: 10.1177/2325967119831272

Jorgensen, D. L. (1989). *Participant Observation: A Methodology for Human Studies*. Thousand Oaks, CA: Sage Publications, Inc.

Keenan, K. A., Wohleber, M. F., Perlsweig, K. A., Baldwin, T. M., Caviston, M., Lovalekar, M., et al. (2017). Association of prospective lower extremity musculoskeletal injury and musculoskeletal, balance, and physiological characteristics in Special Operations Forces. *J. Sci. Med. Sport* 20(Suppl. 4), S34–S39. doi: 10.1016/j.jsams.2017.09.002

Khodoss, F. (2004). *Méditations métaphysiques, traduction de René Descartes*. Paris: Presses Universitaires de France.

Khosrokiani, Z., Letafatkar, A., and Sokhanguei, Y. (2018). Long-term effect of direction-movement control training on female patients with chronic neck pain. *J. Bodywork Movement Therap.* 22, 217–224. doi: 10.1016/j.jbmt.2017.06.004

Kim, J.-E., and Do, K.-S. (2021). Analysis of research trends in selective functional behavior evaluation. *J. Soc. Integr. Med.* 9, 63–73. doi: 10.15268/KSIM.2021.9.2.063

Laborde, S., Dosseville, F., and Allen, M. S. (2016). Emotional intelligence in sport and exercise: a systematic review. *Scand. J. Med. Sci. Sports* 26, 862–874. doi: 10.1111/sms.12510

Lizzio, V. A., Meta, F., Fidai, M., and Makhni, E. C. (2017). Clinical evaluation and physical exam findings in patients with anterior shoulder instability. *Curr. Rev. Musculoskeletal Med.* 10, 434–441. doi: 10.1007/s12178-017-9434-3

Lo Bue, S. (2015). *Hardiness in the Heart of the Military (Doctoral Dissertation)*. Retrieved from: https://lirias.kuleuven.be/1952414?limo=0

Logue, D., Madigan, S. M., Delahunt, E., Heinen, M., Mc Donnell, S.-J., and Corish, C. A. (2018). Low energy availability in athletes: a review of prevalence, dietary patterns, physiological health, and sports performance. *Sports Med.* 48, 73–96. doi: 10.1007/s40279-017-0790-3

Lopes, T. J., Simic, M., Chia, L., Terra, B., Alves, D., Bunn, P., et al. (2021). Trunk endurance, posterior chain flexibility, and previous history of musculoskeletal pain predict overuse low back and lower extremity injury: a prospective cohort study of 545 Navy Cadets. *J. Sci. Med. Sport* 24, 555–560. doi: 10.1016/j.jsams.2020.11.020

Loucks, A. B., Kiens, B., and Wright, H. H. (2011). Energy availability in athletes. *J. Sports Sci.* 29(Suppl. 1), S7–S15. doi: 10.1080/02640414.2011.588958

Lunasco, T., Chamberlin, R. A., and Deuster, P. A. (2019). Human performance optimization: an operational and operator-centric approach. *J. Spec. Ops. Med.* 19, 101–106.

Lyakh, V., Mikołajec, K., Bujas, P., Witkowski, Z., Zajac, T., Litkowycz, R., et al. (2016). Periodization in team sport games - a review of current knowledge and modern trends in competitive sports. *J. Human Kinet.* 54, 173–180. doi: 10.1515/hukin-2016-0053

Malgoyre, A., Sanchez, H., and Koulmann, N. (2015). Éthique du sport et éthique de la guerre : optimisation des performances physiques du combattant. *Méd. Armées* 43, 259–266.

Mattie, C. P., Guest, K., Bailey, S., Collins, J., and Gucciardi, D. F. (2020). Development of a mental skills training intervention for the Canadian Special Operations Forces Command: an intervention mapping approach. *Psychol. Sport Exer.* 50, 101742. doi: 10.1016/j.psychsport.2020.101720

Mayer, J. D., and Salovey, P. (1997). "What is emotional intelligence," in *Emotional Development and Emotional Intelligence: Educational Implications*, eds P. Salovey and D. J. Sluyter (New York, NY: Basic Books), 3–34.

Mayer, J. D., Salovey, P., and Caruso, D. (2000). "Models of emotional intelligence," in *Handbook of Intelligence*, ed R. J. Sternberg (Cambridge: Cambridge University Press), 396–420. doi: 10.1017/CBO9780511807947.019

McCrae, R. R., and Costa, P. T. Jr. (1989). Reinterpreting the myers-briggs type indicator from the perspective of the five-factor model of personality. *J. Pers.* 57, 17–40. doi: 10.1111/j.1467-6494.1989.tb00759.x

McGovern, R. P., Martin, R. L., Christoforetti, J. J., and Kivlan, B. R. (2018). Evidence-based procedures for performing the single leg squat and step-down tests in evaluation of non-arthritic hip pain: a literature review. *Int. J. Sports Phys. Ther.* 13, 526–536. doi: 10.26603/ijspt20180526

McIntyre, A. (2007). *Participatory Action Research*. Thousand Oaks, CA: Sage Publications, Inc. doi: 10.4135/9781483385679

McTaggart, R. (1991). Principles for participatory action research. *Adult Educ. Q.* 41, 168–187. doi: 10.1177/0001848191041003003

Meeusen, R., Duclos, M., Foster, C., Fry, A., Gleeson, M., Nieman, D., et al. (2013). Prevention, diagnosis, and treatment of the overtraining syndrome: joint consensus statement of the European College of Sport Science and the American College of Sports Medicine. *Med. Sci. Sports Exerc.* 45, 186–205. doi: 10.1249/MSS.0b013e318279a10a

Métairie, R. (2021). *Paris 2024 : le discours indécent du coach Macron*. Paris: Libération.

Momen, N., Taylor, M. K., Pietrobon, R., Gandhi, M., Markham, A. E., Padilla, G. A., et al. (2010). Initial validation of the military operational risk taking scale (MORTS). *Milit. Psychol.* 22, 128–142. doi: 10.1080/08995601003638942

Monk, T. H., Reynolds, C. F. III., Kupfer, D. J., Buysse, D. J., Coble, P. A., Hayes, A. J., et al. (1994). The pittsburgh sleep diary. *J. Sleep Res.* 3, 111–120. doi: 10.1111/j.1365-2869.1994.tb00114.x

Mujika, I., Halson, S., Burke, L. M., Balagué G., and Farrow, D. (2018). An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. *Int. J. Sports Physiol. Perform.* 13, 538–561. doi: 10.1123/ijspp.2018-0093

Mullie, P., Clarys, P., De Bry, W., and Geeraerts, P. (2019). Energy availability and nutrition during a Special Force Qualification Course (Q-Course). *J. R. Army Med. Corps* 165, 325–329. doi: 10.1136/jramc-2018-001059

Myers, I. B. (1962). *The Myers-Briggs Type Indicator: Manual*. Palo Alto, CA: Consulting Psychologists Press. doi: 10.1037/14404-000

Nadler, S. F., Malanga, G. A., Feinberg, J. H., Prybicien, M., Stitik, T. P., and DePrince, M. (2001). Relationship between hip muscle imbalance and occurrence of low back pain in collegiate athletes: a prospective study. *Am. J. Phys. Med. Rehabil.* 80, 572–577. doi: 10.1097/00002060-200108000-00005

NATO SOF Medical standards and training directive (2009). *Version 1.0, October 2009, Nato Special Operations Coordination Centre, Supreme Heaoquarters Allied Powers Europe, 7010 Shape Belgium*.

Nee, R. J., Jull, G. A., Vicenzino, B., and Coppieters, M. (2012). The validity of upper-limb neurodynamic tests for detecting peripheral neuropathic pain. *J. Orthop. Sports Phys. Ther.* 42, 413–424, doi: 10.2519/jospt.2012.3988

Nixdorf, I., Frank, R., and Beckmann, J. (2015). An explorative study on major stressors and its connection to depression and chronic stress among German elite athletes. *Adv. Phys. Educ.* 5, 255–262. doi: 10.4236/ape.2015.54030

Ogińska, H. (2011). Can you feel the rhythm? A short questionnaire to describe two dimensions of chronotype. *Personal. Individual Differe.* 50, 1039–1043, doi: 10.1016/j.paid.2011.01.020

Oginska, H., Mojsa-Kaja, J., and Mairesse, O. (2017). Chronotype description: in search of a solid subjective amplitude scale. *Chronobiol. Int.* 34, 1388–1400. doi: 10.1080/07420528.2017.1372469

Otte, F. W., Rothwell, M., Woods, C., and Davids, K. (2020). Specialist coaching integrated into a department of methodology in team sports organisations. *Sports Med Open.* 6, 55. doi: 10.1186/s40798-020-00284-5

Parr, J. J., Clark, N. C., Abt, J. P., Kresta, J. Y., Keenan, K. A., Kane, S. F., et al. (2015). Residual impact of previous injury on musculoskeletal characteristics in special forces operators. *Orthop. J. Sports Med.* 3, 2325967115616581. doi: 10.1177/2325967115616581

Pattyn, N. (2009). On the Persistance of Dualism in our so-called Unified Neurosciences: the case of the autonomic nervous system. *Psychol. Belg.* 49, 101–110. doi: 10.5334/pb-49-2-3-101

Pattyn, N., Van Cutsem, J., Dessy, E., and Mairesse, O. (2018). Bridging exercise science, cognitive psychology, and medical practice: is "Cognitive Fatigue" a remake of "The Emperor's New Clothes"? *Front. Psychol.* 9, 1246. doi: 10.3389/fpsyg.2018.01246

Pattyn, N., and Vliegen, R. (2019). *Better, Faster, Stronger. . . But Not Bigger: le programme de gestion de performance humaine au sein des forces spéciales*. Belgisch Militair Tijdschrift / Revue Militaire Belge.

Paulhus, D. L. (1984). Two-component models of socially desirable responding. *J. Pers. Soc. Psychol.* 46, 598–609. doi: 10.1037/0022-3514.46.3.598

Paulhus, D. L. (1991). "Measurement and control of response bias," in *Measures of Personality and Social Psychological Attitudes*, eds J. P. Robinson, P. R. Shaver, and L. S. Wrightsman (Cambridge, MA: Academic Press), 17–59. doi: 10.1016/B978-0-12-590241-0.50006-X

Pemrick, M. D. (1999). *Physical Fitness and the Seventy-Fifth Ranger Regiment: The Components of Physical Fitness and the Ranger Mission*. (Master of Military Art and Science Thesis). US Army Command and General Staff College, Fort Leavenworth, Kansas. Available online at: https://apps.dtic.mil/sti/pdfs/ADA367762.pdf

Picano, J. J., Roland, R. R., Williams, T. J., and Bartone, P. T. (2017). "Assessment of elite operational personnel," in *Handbook of Military Psychology*, eds

S. V. Bowles and P. T. Bartone (Washington, DC: Springer), 277–289. doi: 10.1007/978-3-319-66192-6_17

Pleban, R. J., Allentoff, H., and Thompson, T. (1989). *Preliminary assessment of selected predictors of special forces qualification course success*. US Army Research Institute for the Behavioral and Social Sciences. Fort Belvoir, VA: Defense Technical Information Center. Available online at: https://apps.dtic.mil/sti/pdfs/ADA213201.pdf

Pol, R., Balagué, N., Ric, A., Torrents, C., Kiely, J., and Hristovski, R. (2020). Training or Synergizing? complex systems principles change the understanding of sport processes. *Sports Med. Open* 6, 128. doi: 10.1186/s40798-020-00256-9

Rietjens, G., Plasqui, G., Frenken, D., and Most, J. (2021). Nutritional requirements during training for special operation forces. *Res. Square*. doi: 10.21203/rs.3.rs-95427/v1

Sainz, J. (2020). *Team Sports Training: The Complexity Model*. Milton Park: Routledge.

Salovey, P., and Mayer, J. D. (1990). Emotional intelligence. *Imagin. Cogn. Pers.* 9, 185–211. doi: 10.2190/DUGG-P24E-52WK-6CDG

Sharp, M. A., Knapik, J. J., Walker, L. A., Burrell, L., Frykman, P. N., Darakjy, S. S., et al. (2008). Physical fitness and body composition after a 9-month deployment to Afghanistan. *Med. Sci. Sports Exerc.* 40, 1687–1692. doi: 10.1249/MSS.0b013e318176b978

Sihawong, R., Janwantanakul, P., Sitthipornvorakul, E., and Pensri, P. (2011). Exercise therapy for office workers with nonspecific neck pain: a systematic review. *J. Manipulative Physiol. Ther.* 34, 62–71. doi: 10.1016/j.jmpt.2010.11.005

Solberg (2017). *Mediators and Moderators (Predictors) of Injuries Among Norwegian Naval Special Forces Operators – A 5 Year Longitudinal Study. Conference presentations at the 1st CANSOFCOM Human Performance Symposium*. Ottawa, ON.

Solberg, P. A., Paulsen, G., Slaathaug, O. G., Skare, M., Wood, D., Huls, S., et al. (2015). Development and implementation of a new physical training concept in the norwegian navy special operations command. *J. Strength. Cond. Res.* 29(Suppl. 11), S204–S210. doi: 10.1519/JSC.0000000000001085

Soltanzadeh, S., and Mooney, M. (2016). Systems thinking and team performance analysis. *Int. Sport Coach. J.* 3, 184–191. doi: 10.1123/iscj.2015-0120

Southerst, D., Côté, P., Stupar, M., Stern, P., and Mior, S. (2013). The reliability of body pain diagrams in the quantitative measurement of pain distribution and location in patients with musculoskeletal pain: a systematic review. *J. Manipulative Physiol. Ther.* 36, 450–459. doi: 10.1016/j.jmpt.2013.05.021

Spielberger, C. D. (1983). State-trait anxiety inventory for adults (STAI-AD) [Database record]. *APA PsycTests*. doi: 10.1037/t06496-000

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., and Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Sporiš, G., Harasin, D., Bok, D., Matika, D., and Vuleta, D. (2012). Effects of a training program for special operations battalion on soldiers' fitness characteristics. *J. Strength. Cond. Res.* 26, 2872–2882. doi: 10.1519/JSC.0b013e318242966c

Spradley, J. P. (2016). *Participant Observation*. Long Grove, IL: Waveland Press.

Stein, R., Swan, A. B. (2019). Evaluating the validity of Myers-Briggs Type Indicator theory: a teaching tool and window into intuitive psychology. *Soc. Personal Psychol. Compass*. 13, e12434. doi: 10.1111/spc3.12434

Stevens, V. K., Bouche, K. G., Mahieu, N. N., Cambier, D. C., Vanderstraeten, G. G., and Danneels, L. A. (2006). Reliability of a functional clinical test battery evaluating postural control, proprioception and trunk muscle activity. *Am. J. Phys. Med. Rehabil.* 85, 727–736. doi: 10.1097/01.phm.0000233180.88299.f6

Tassone, E. C., and Baker, B. A. (2017). Body weight and body composition changes during military training and deployment involving the use of combat rations: a systematic literature review. *Br. J. Nutr.* 117, 897–910. doi: 10.1017/S0007114517000630

Tennent, T. D., Beach, W. R., and Meyers, J. F. (2003). A review of the special tests associated with shoulder examination. Part II: laxity, instability, and superior labral anterior and posterior (SLAP) lesions. *Am. J. Sports Med.* 31, 301–307. doi: 10.1177/03635465030310011101

Troxel, W. M., Shih, R. A., Pedersen, E. R., Geyer, L., Fisher, M. P., Griffin, B. A., et al. (2015). *Sleep in the Military: Promoting Healthy Sleep Among U.S. Servicemembers*. Santa Monica, CA: RAND Corporation.

Tucker, A. M., Dinges, D. F., and Van Dongen, H. P. (2007). Trait interindividual differences in the sleep physiology of healthy young adults. *J. Sleep Res.* 16, 170–180. doi: 10.1111/j.1365-2869.2007.00594.x

Van Damme, B., Stevens, V., Perneel, C., Van Tiggelen, D., Neyens, E., Duvigneaud, N., et al. (2014). A surface electromyography based objective method to identify patients with nonspecific chronic low back pain, presenting a flexion related movement control impairment. *J. Electromyography Kinesiol.* 24, 954–964. doi: 10.1016/j.jelekin.2014.09.007

Vaughan, R. S., Hagyard, J. D., Brimmell, J., and Edwards, E. J. (2021). The effect of trait emotional intelligence on working memory across athletic expertise. *J. Sports Sci.* 39, 629–637. doi: 10.1080/02640414.2020.1840039

Vine, C., Coakley, S., Myers, S. D., Blacker, S. D., and Runswick, O. (2021). Transferability of military specific cognitive research to military training and operations. *Front. Psychol.* 12, 604803. doi: 10.3389/fpsyg.2021.604803

Vrijkotte, S., Roelands, B., Meeusen, R., and Pattyn, N. (2016). Sustained military operations and cognitive performance. *Aerospace Med. Human Perform.* 87, 718–727. doi: 10.3357/AMHP.4468.2016

Vrijkotte, S., Roelands, B., Pattyn, N., and Meeusen, R. (2018). The overtraining syndrome in soldiers: insights from the sports domain. *Milit. Med.* 184, 192–200. doi: 10.1093/milmed/usy274

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale, 4th Edn (WAIS-IV)*. APA PsycTests.

Wrangham, R. (1999). Evolution of coalitionary killing. *Yrb. Phys. Anthropol.* 42, 1–30. doi: 10.1002/(SICI)1096-8644

Young, J. L., Walker, D., Snyder, S., and Daly, K. (2014). Thoracic manipulation versus mobilization in patients with mechanical neck pain: a systematic review. *J. Man. Manip. Ther.* 22, 141–153. doi: 10.1179/2042618613Y.0000000043

Conflict of Interest: AC is employed by Brainwise, Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Advantages of publishing in Frontiers

OPEN ACCESS
Articles are free to read for greatest visibility and readership

FAST PUBLICATION
Around 90 days from submission to decision

HIGH QUALITY PEER-REVIEW
Rigorous, collaborative, and constructive peer-review

TRANSPARENT PEER-REVIEW
Editors and reviewers acknowledged by name on published articles

Frontiers
Avenue du Tribunal-Fédéral 34
1005 Lausanne | Switzerland

Visit us: www.frontiersin.org
Contact us: frontiersin.org/about/contact

REPRODUCIBILITY OF RESEARCH
Support open data and methods to enhance research reproducibility

DIGITAL PUBLISHING
Articles designed for optimal readership across devices

FOLLOW US
@frontiersin

IMPACT METRICS
Advanced article metrics track visibility across digital media

EXTENSIVE PROMOTION
Marketing and promotion of impactful research

LOOP RESEARCH NETWORK
Our network increases your article's readership