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Physical culture from an interdisciplinary perspective

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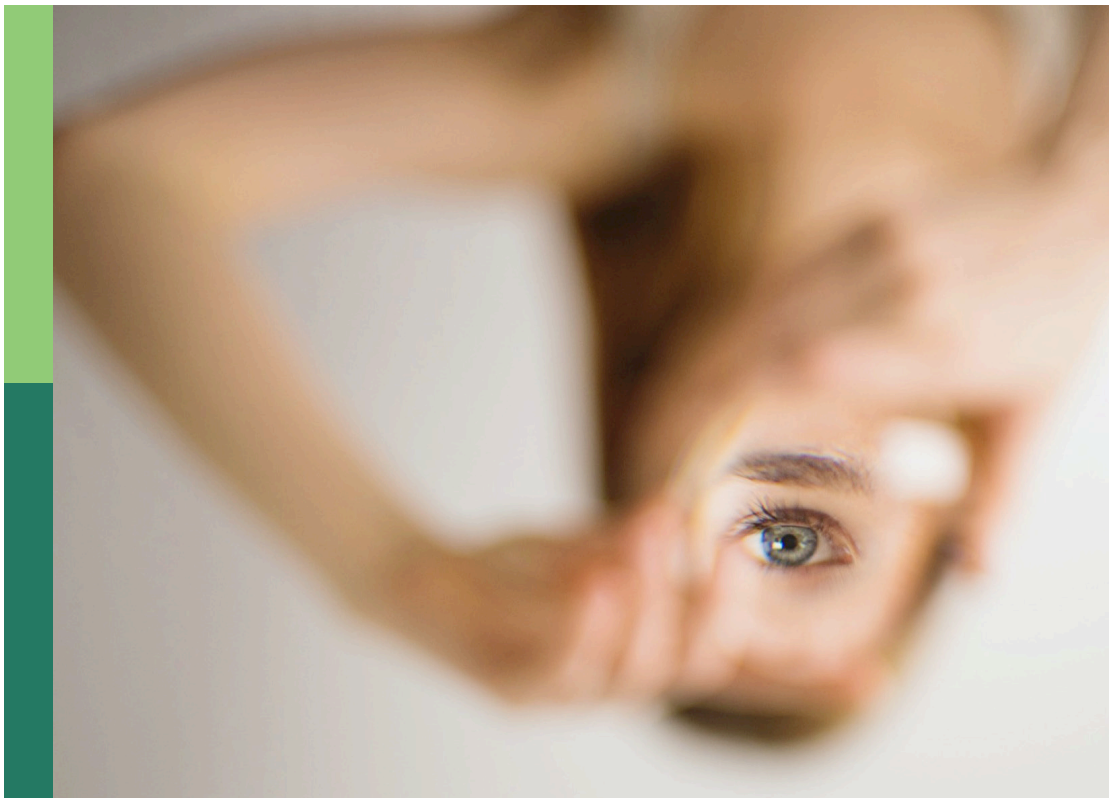

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Physical culture from an interdisciplinary perspective

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Editorial: Physical culture from an interdisciplinary perspective

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physical education, physiotherapy, sport, tourism, recreation

Editorial on the Research Topic
Physical culture from an interdisciplinary perspective

About physical culture sciences

Physical culture is the totality of activities according to the rules and norms of behavior accepted in a given social environment. These activities are aimed at health-promoting values. The result is correct psycho-physical development of an individual through the outcomes of these activities. One can participate in physical culture through five areas: physical education, physiotherapy, sport, tourism, and recreation. The area of physical education should be understood as guiding people's physical development and health through physical activity, developing fitness and efficiency and shaping their correct posture, as well as prosocial attitudes as part of school education. The area of physiotherapy, on the other hand, aims to restore fitness and function in everyday life for people affected by injury, illness or disability through exercise and physical therapy treatments. The area of sport, on the other hand, is concerned with all forms of physical activity which, through casual or organized participation of sporting persons, are aimed at achieving results in competition at all levels according to specific regulations. The next area, tourism, refers to all activities that aim to explore the world's resources and is carried out by traveling physically active way. The last area is recreation, which refers to all forms of physical activity undertaken for leisure, psycho-physical renewal and relaxation. As a result of the above, it has been concluded that the physical culture sciences are concerned with the study of the stimulation of the human organism, the adaptation of this organism to the environment, the compensation of its deficits and the correction of its postural defects. Therefore, it is possible to state conclusions in this discipline of sciences about the values of the body in the health, utilitarian, aesthetic, hedonistic and agonistic sense.

Directions for integrating psychology into physical culture sciences

Psychology is interdisciplinary because it is important in every aspect of social life. Psychology also has a place in the field of physical culture. In the curricula of these studies, there are specialized subjects in the field of psychology: physical activity (concerning physical

education), rehabilitation (concerning physiotherapy), sport (concerning sport), tourism (concerning tourism), and leisure time (concerning recreation). In this sense, psychology and physical culture have the same goal, which is health-promoting values that translate into proper psychophysical development of the society. The above justifies the advisability of editing a Research Topic of Frontiers in Psychology under the title "*Physical culture from an interdisciplinary perspective*". For this reason, the editors aimed at presenting the results of research in physical culture sciences from various scientific disciplines the issues of which are in the curricula of studies in physical education, physiotherapy, sport, tourism and recreation. The interdisciplinary view of 21st century problems points to the important role of physical culture as an element of social life.

Contents of the Research Topic

In the first paper, Prokopczyk and Wochyński verified the effect of the training process with the use of the Special Aviation Gymnastics Instruments (SAGI) on the improvement of psychomotor ability among cadets, expressed as an increase in the percentage ability to perform all tasks and the number of coils per loop. It was found that the training process on the SAGI raised the psychomotor level of the cadets. This study was a pilot study.

In the next paper, Ma analyzed the case of the Shanghai municipality to understand the complexity of the change in elite sports at the provincial level. Based on semi-structured face-to-face interviews and official and semi-official documents, information on strategies for reviewing sport policy directions was provided. Guangdong was found to serve as a powerful impetus for elite sports policy in Shanghai. It is reinforced by the activities of Shanghai University of Sports. And the general director of the Shanghai Sports Administration plays a key role in promoting sport policy proposals.

In the third paper, Zhigang et al. presented the factors influencing significant sport consumption and the mechanism of its impact. Based on their study in China, they found that social needs have a significant positive effect on sports consumption behavior through the mediating effect of team membership and the drive for self-esteem. However, self-enhancement motivation does not have a mediating effect on the relationship between social needs and sport consumption.

In the fourth paper, Montt-Blanchard et al. presented issues of designing opportunities to manage the barriers imposed by type 1 diabetes (T1D) that were gained during marathon running. Six insights related to T1D self-management were identified and analyzed in relation to the associated design tools. Reference was made to the important role of physical activity in crossing human boundaries and the need for further research in physical culture and health psychology.

In the following paper, Jaworski, Lech, Witkowski et al. determined the influence of training and selection on postural stability and its relationship with sport level in judo practitioners aged 11–14 years. Their balance was assessed using the CQ Stab 2P stabilographic platform (CQ Elektronik System, Poland). It was found that the mean frequency (MF) of center of pressure (COP) was significantly higher in judokas than in non-trainees. The correlations between the other values of the parameters characterizing balance level and sport level were statistically insignificant.

In the following article, Siekanska et al. examined the validity of the Polish Short Form version of the Self-Regulated Learning-Sport Practice survey among competitive athletes. They analyzed factor validity and reliability, criterion validity, and convergent validity of the Polish Short Form survey. Athletes at amateur, regional, national, and international elite levels completed the survey, along with concurrent subscales: General Self-Efficacy Scale (GSES); Metacognitive Self-Scale (MS-24); Action Control Scale (ACS-90). Based on strong criterion-relevance and moderate evidence of convergent validity, the Polish Short Form of the Self-Regulated Learning-Sport Practice survey was found to be a promising tool for use in Polish sport and is subject to further validation.

In the seventh paper, Piepiora et al. compared personalities of Polish mountaineers. For this purpose, they surveyed a population of male and female Polish mountaineers: Alpine climbers and Himalayan climbers. The Big Five model was used, including the NEO-FFI Personality Questionnaire. It was found that a significant difference between the personalities of Polish Alpine climbers and Polish Himalayan climbers in terms of agreeableness was found only among women: female Alpine climbers are more agreeable than female Himalayan climbers, which may imply ethical dilemmas in the high mountains.

In another paper, Mackala et al. determined the impact of marathon performance on muscle stiffness in runners over 50 years of age. Thirty-one long-distance runners aged 50–73 years participated in the experiment. Quadriceps and calf muscle stiffness were measured using a Myoton device in two independent tests: the day prior to the marathon and 30 min after the completion of a marathon run. Reduced muscle stiffness was found, but only in the triceps calf muscle in the dominant (left) leg. The research should be continued and an optimal evaluation should also address direct and indirect analyses of running economy, running technique, and HRmax and VO_2max variables.

In the following paper, Bibrowicz et al. determined the asymmetry of the pelvis in Polish young adults aged 19–29. The prevalence of spatial asymmetry of the pelvis was analyzed based on the author's clinical classification and the significance of body weight and height for the asymmetries analyzed on a sample of 300 young adults. Asymmetries in the pelvis area were observed in less than three-quarters of the examined population. Oblique pelvis was found in less than a quarter of women and in more than one-third men with the predominant structural asymmetries. Rotated pelvis was observed in more than one third of women and men with dominating functional asymmetries.

In the 10th paper, Jaworski, Lech, Żak et al. studied the relationships between selected indices of postural stability and sports performance in elite badminton players. The pilot study examined 10 elite players from the Polish national badminton team. The scope of the study included basic somatic characteristics such as body height, body weight, BMI and training experience. The Microgate GYKO inertial sensor system was used to assess the postural stability of the athletes. The athletes with higher ranking positions were found to have higher levels of postural stability in the tests. Furthermore, higher correlation coefficient values were

found for the test performed in single-leg standing. This indicates that special attention should be paid to the development of levels of postural stability in order to improve sports performance among badminton players.

In the last paper Stackeová et al. did a study of a modification of EAT-26 questionnaire to detect pathological eating behavior in competitive athletes. On the basis of the EAT-26 questionnaire, a modification was created for use among professional athletes. It was then validated among athletes in aesthetic sports with a sample of 100 respondents aged 16–26 years. Five strong factors were identified: diet control, weight control, training obsession, appetite, calorie counting; which can be defined as significant factors that influence the onset of disordered eating behavior or the subsequent development of eating disorders. Respondents from the bodybuilding and fitness sector scored highest on average. It was concluded that disordered eating behaviors and eating disorders are being hidden in the sporting environment and that diagnosis in this environment is difficult.

Author contributions

PP: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing—original draft, Writing—review and editing. ZP: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing—original draft, Writing—review and editing. DS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing—original draft, Writing—review and editing. JB: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing—original draft, Writing—review and editing.

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.

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Influence of a special training process on the psychomotor skills of cadet pilots – Pilot study

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Objectives: The aim of the pilot study was to check the influence of the training process on the Special Aviation Gymnastics Instruments (SAGI) on the improvement of the psychomotor skills, expressed as an increase in the percentage of ability to perform all tasks and the number of reels on a loop.

Materials and methods: Cadets - second year pilots (n=20), male, mean age 20.8years old, studying at the faculty of a pilot. Cadets were carrying out a 40-h special pilot training program on SAGI. They were subjected to two exercise tests (reels forward on looping), before and after the period of special training. Exercise tests were performed with the use of a diagnostic and training device used to assess psychomotor skills. During two tests, heart rate (HR) and blood pressure were measured. The obtained results were analysed statistically.

Results: There was a statistically significant increase in the percentage of ability to perform all tasks (p<0.01) and a statistically insignificant increase in the number of reels forward on looping, in test II in relation to test I. A significant increase was found in the correct execution of arithmetic operations (p<0.05) in test II in relation to test I. In the remaining tests, an increase in results in test II was noted, but it was not statistically significant. There was a significant correlation between the percentage ability to perform all tasks and the number of completed reels in test I (p<0.05) and insignificant in test II. In test II, a statistically insignificant higher level of heart rate and blood pressure before and after the effort was noted, compared to test I.

Conclusion: It was found that the training process on SAGI increased the psychomotority level by increasing the percentage of ability to perform all tasks and the number of reels, in test II in relation to test I.

KEYWORDS

psychomotor skills, motor skills, sensoric, special training, diagnostic and training device, special aviation gymnastics instruments

Introduction

The process of special pilot skills preparation is a very important factor in modern flight preparation (Alexander and Stead, 2018). It is aimed at preparing the pilot for functioning and effective performance of complex and demanding tasks in the pilot working environment (Carretta, 2000; Li et al., 2005). As shown in other studies, for the conduct of an air mission by a pilot, required is appropriate level of preparation giving that allows possibility of processing a large amount of sensory information (Paśko et al., 2022). The level of this preparation is one of the determinants of the level of safety and effectiveness of the flight mission. Working environment of a military pilot requires a high level of psychomotor skills (McMahon and Newman, 2015). Researchers are studying the issues of psychomotorism for several dozen years. Despite many changes, testing of this feature is still present in modern training and selection systems for military pilots (Clem, 2020). Psychomotor skills is a motor activities that involve a significant perceptual and response load (Chaiken et al., 2000). The work of a military pilot requires highly specialized preparation including response time (Temme et al., 1995; Griffin and Koonce, 2009), information processing efficiency and motor skills - airplane operator activities (Astani and Macarie, 2013). Moreover, his psychophysical predispositions are very important, giving him high tolerance to negative flight factors (mainly acceleration; Wojtkowiak, 1989; Street Jr and Dolgin, 1994; McMahon and Newman, 2018), neurosensory predispositions, his level of efficiency and physical skills (Wochyński et al., 2010a; Kattenbach, 2017; McMahon, 2019). Due to such a wide range of skills required from a pilot, it is necessary to monitor the effects of the training process and modify it if necessary. Until now, Düffoure apparatus has been used most frequently to check the level of the psychomotor skills which was a result of the effectiveness of the military pilot training process. It was used to determine the level of visual-motor coordination before and after training on the Special Aviation Gymnastics Instruments (SAGI), including: gyroscope, Rhine wheel and looping (Kobos et al., 1994). The appearance and structure of these instruments is presented in other scientific papers (Wochyński and Sobiech, 2014, 2015, 2017). One of the most important elements of pilot training in preparation for flight is to achieve a habituation in psychomotor skills, high acceleration tolerance and spatial orientation (Wochyński et al., 2010b).

Taking into account the specificity of pilot's work and the tasks facing him, it is important from the point of view of work efficiency to assess the psychomotor response during the exercises, and not only before and after the training. Therefore, in the present study, a diagnostic and training device was used to assess the level of psychomotority during physical effort. This test involves the use of complex visual-motor stimuli and the need to answer questions located in the central field of vision (in a specific time standard), while performing specific exercises (reels forward on the looping). The application of this test gives an opportunity to assess the ability to respond appropriately to a rapidly changing situation in the working environment of a military pilot (Glicksohn and Naor-Ziv, 2016). Psychomotor efficiency at the level of visual - motor coordination can be manifested in the reaction time parameters, i.e., the speed and correctness of their implementation (making a mistake; McMahon, 2019). Response errors may arise from a disturbance between stimulus and response, in a specific time standard. The test of visual - motor coordination efficiency during physical exertion is similar to the working conditions of a pilot during an air mission. Therefore, the authors undertook research on cognitive processes within in a specific time standard using the psychomotor test in cadets pilots during physical effort.

Objectives

The aim of the pilot study was to check the influence of the training process on the Special Aviation Gymnastics Instruments (SAGI) on the improvement of the psychomotor skills. In this pilot study the authors put forward a hypothesis that the training process on SAGI will improve the level of psychomotor skills, measured with a diagnostic and training device, through a percentage increase in the ability to perform tasks (answers to questions in the central field of vision) and the level of motor skills (the number of reels made forward on the loop), in the sample after the training process is completed in relation to the sample before the process begins. Moreover, the authors asked a research question whether the improvement of psychomotor skills after the training process will be confirmed by lowering the correlation between the percentage ability to complete the task [%] and number of completed reels on the looping?

Materials and methods

Participants

The test included 20 cadets - pilots, second year, male, studying at the faculty of a military pilot, at the Military University of Aviation in Dęblin. The average age of the respondents is 20.8 years. The cadets implemented a special educational program, based on the Special Aviation Gymnastics Instruments (SAGI), to improve the level of psychomotority (Wochyński et al., 2010a). The test was carried out without a control group, due to the difficulty and specificity of the exercises included in the implemented test.

Heart rate and blood pressure

Cadets had the heart rate and blood pressure measured before and immediately after the test, at the beginning and at the end of the training process. The measurement was performed with the heart rate and blood pressure measuring device, Microlife AG, type BP A2 Basic.

FIGURE 1
The test person with diagnostic and training device.

FIGURE 2
Operator's station.

Description of the test

The test person was wearing a diagnostic and training device (Figure 1), consisting of a backpack and special glasses (opaque). The test person was attached to a looping swing (arm and leg mount). The test person set the looping swing in motion with his own muscles. The start of the test began when the test person was parallel to the ground. The backpack contained a small computer to communicate the tasks to be performed by the trainee in time standard. The tasks were sent wirelessly from the computer, from the operator (Figure 2) using a relay station, directly to the small computer. The test person was to solve 5 tasks: counting paratroopers in the same colour, counting cars in the same colour, solving arithmetic operations, counting shapes of one type, counting shapes in the same colour. All tasks were displayed in the central field of vision. In addition, immediately after the end of the test, 6th task was performed - a synthetic memory test. Each subsequent test person had a changed order and content of task display. A person at the operator's station had a preview of the correct answers, marked the correctness of the test person's answers and controlled the test time (Wochyński et al., 2010a). The tasks and answers were archived by the test operator, at the operator's station using the diagnostic and training device, immediately after the end of the test. After the end of the test, the operator printed out the report, which showed the test results in percentages and recorded the number of reels made forward. The whole test time was 128 s.

Training program

The training program on the Special Aviation Gymnastics Instruments included 40 training hours and was divided into 3 parts. The first one covered 26 h and concerned teaching and improving individual exercises. The second part included 8 h of teaching and improving team exercises. The third part was 6 h long, focused on individual spatial orientation and its improvement, with the use of the air environment visualisation system on SAGI. The training program was carried out in the zone of metabolic - aerobic changes. Such a structure of the training process was to ensure adaptation to specific coordination motor skills under the pilot working conditions (Wochyński et al., 2010a). Special pilot training was carried out over 80 days.

Statistical analysis

Descriptive statistics were used for calculating the arithmetic mean and standard deviation for tests I and II. Results of tests I and II were analyzed for normal distribution using Kolmogorov–Smirnov test, skewness and kurtosis. The r-Pearson correlation between all tested variables was calculated. The difference of results between tests I and II was calculated by analysis of variance (ANOVA) with repeated measurements using the Tukey HSD post-hoc test for pairwise comparison. Effect sizes were calculated using Cohen's d and interpreted as low ($d = 0.20$ to 0.49), moderate ($d = 0.50$ to 0.79), and high ($d > 0.80$; Cohen, 1988). The obtained values were considered statistically significant when p was less than 0.05. Statistical analysis was performed using the Statistica 13.3 program. The G * Power program was used to assess the sample size (Faul et al., 2007). For evaluate the sample size with the size effect $f2 = 0.25$ was assume an alpha error of 0.05 and a test's power of 0.80. The required size of the total sample was estimated at 25 people. Due to the length of the training process, the final analysis was included 20 people.

TABLE 1 Elements of normal distribution in somatic and hemodynamic data before and after the training process in cadets pilots (n=20).

Variable	Before training process				After training process			
	M ± SD	K-S	Skewness	Kurtosis	M ± SD	K-S	Skewness	Kurtosis
Age [years]	20.8 ± 1.30	0.31	2.61	6.84	21.1 ± 1.29	0.31	2.61	6.84
Body height [cm]	177.30 ± 7.54	0.11	0.54	1.71	177.3 ± 7.52	0.11	0.52	1.76
Body weight [kg]	72.21 ± 8.09	0.11	0.19	−0.88	73.99 ± 9.1	0.11	0.23	−0.85
BMI [kg/m^2]	22.95 ± 1.96	0.12	0.18	−0.69	23.5 ± 2.41	0.14	0.48	−0.37
Systolic pressure before test [mm Hg]	135.3 ± 12.37	0.14	0.73	0.61	140.5 ± 10.07	0.12	−0.04	0.79
Diastolic pressure before test [mm Hg]	78.85 ± 10.87	0.10	0.21	0.009	84.3 ± 11.32	0.14	0.94	1.44
Systolic pressure after test [mm Hg]	152.8 ± 18.10	0.14	−0.89	1.25	158.1 ± 18.97	0.13	0.32	−0.31
Diastolic pressure after test [mm Hg]	86.4 ± 18.10	0.09	0.61	0.50	90.05 ± 13.41	0.18	0.79	−0.26
HR before test [bpm]	84.65 ± 14.68	0.14	1.06	1.28	80.7 ± 16.68	0.13	1.01	2.10
HR after test [bpm]	116.4 ± 13.56	0.12	0.17	1.44	112.7 ± 15.38	0.14	0.31	0.34

M ± SD—Mean, Standard Deviation; K-S-Kolmogorov–Smirnov test.

TABLE 2 Difference in somatic data and in hemodynamic parameters during the psychomotor test before and after the training process of cadet pilots (n=20).

Variable	Before training process M ± SD	After training process M ± SD	Cohen's d test	F	p
Age [years]	20.8 ± 1.30	21.1 ± 1.29	0.23	0.000	1.00
Body height [cm]	177.30 ± 7.54	177.38 ± 7.52	0.01	0.0009	0.98
Body weight [kg]	72.21 ± 8.09	73.99 ± 9.1	0.20	0.42	0.52
BMI [kg/m^2]	22.95 ± 1.96	23.5 ± 2.41	0.25	0.62	0.43
Systolic pressure before test [mm Hg]	135.35 ± 12.37	140.5 ± 10.07	0.45	2.08	0.16
Diastolic pressure before test [mm Hg]	78.85 ± 10.87	84.3 ± 11.32	0.49	2.41	0.13
Systolic pressure after test [mm Hg]	152.85 ± 18.10	158.1 ± 18.97	0.28	0.80	0.37
Diastolic pressure after test [mm Hg]	86.4 ± 18.10	90.05 ± 13.41	0.23	0.97	0.33
HR before test [bpm]	84.65 ± 14.68	80.7 ± 16.68	0.25	0.63	0.43
HR after test [bpm]	116.4 ± 13.56	112.7 ± 15.38	0.25	0.65	0.42

M ± SD—Mean, standard deviation; p-value of the difference.

TABLE 3 Elements of normal distribution in individual psychomotor skills before and after the training process in cadets pilots (n=20).

Variable	Before training process				After training process			
	M ± SD	K-S	Skewness	Kurtosis	M ± SD	K-S	Skewness	Kurtosis
Percentage ability to complete the task [%]	65.6 ± 24.51	0.21	−0.23	−0.85	86.4 ± 13.05	0.20	−0.37	−1.13
Counting paratroopers in the same colour [%]	80.0 ± 0.41	0.48	−1.62	0.69	90.0 ± 0.31	0.52	−2.88	7.03
Counting cars in the same colour [%]	75.0 ± 0.44	0.46	−1.25	−0.49	95.0 ± 0.22	0.53	−4.47	20.00
Arithmetic actions [%]	40.0 ± 0.50	0.38	0.44	−2.01	75.0 ± 0.44	0.46	−1.25	−0.49
Counting shapes of one type [%]	70.0 ± 0.47	0.43	−0.94	−1.24	90.0 ± 0.31	0.52	−2.88	7.03
Counting shapes in the same colour [%]	85.0 ± 0.37	0.50	−2.12	2.77	95.0 ± 0.22	0.53	−4.47	20.00
Synthetic memory test [%]	50.0 ± 0.51	0.33	0.000	−2.23	75.0 ± 0.44	0.46	−1.25	−0.49
Number of completed reels	32.55 ± 21.97	0.18	−0.30	−1.55	40.2 ± 20.06	0.25	−0.50	−0.60

M ± SD—Mean, standard deviation; K-S-Kolmogorov–Smirnov test.

Results

Descriptive statistics were used for calculating the arithmetic mean, Kolmogorov–Smirnov test, skewness and kurtosis, Cohen d for tests I and II (Tables 1–4). A statistically insignificant increase in blood pressure and a decrease in heart rate before and after the training process was found (Table 5).

During the second test, a statistically significant (at $p < 0.01$) percentage increase in the ability to perform all tasks in relation to the first test was found. Among the specified tasks, a statistically

TABLE 4 Difference in individual psychomotor skills before and after the training process in cadets pilots (n=20).

Variable	Before training process M ± SD	After training process M ± SD	Cohen's d test	F	p
Percentage ability to complete the task [%]	65.6 ± 24.51	86.4 ± 13.05	1.06	11.22	<0.01
Counting paratroopers in the same colour [%]	80.0 ± 0.41	90.0 ± 0.31	0.27	0.76	0.38
Counting cars in the same colour [%]	75.0 ± 0.44	95.0 ± 0.22	0.57	3.23	0.08
Arithmetic actions [%]	40.0 ± 0.50	75.0 ± 0.44	0.74	5.44	<0.05
Counting shapes of one type [%]	70.0 ± 0.47	90.0 ± 0.31	0.50	2.53	0.12
Counting shapes in the same colour [%]	85.0 ± 0.37	95.0 ± 0.22	0.32	1.08	0.30
Synthetic memory test [%]	50.0 ± 0.51	75.0 ± 0.44	0.52	2.71	0.11
Number of completed reels	32.55 ± 21.97	40.2 ± 20.06	1.35	1.32	0.26

M ± SD—Mean, standard deviation; p-value of the difference.

TABLE 5 Somatic data and haemodynamic parameters during the psychomotor test before and after the training process in cadet pilots.

Variable	Before training Process	After training Process	Significance value
Age [years]	20.8 ± 1.30	21.1 ± 1.29	0.97
Body height [cm]	177.3 ± 7.54	177.38 ± 7.52	0.98
Body weight [kg]	72.21 ± 8.09	73.99 ± 9.1	0.52
BMI [kg/m^2]	22.95 ± 1.96	23.5 ± 2.41	0.43
Systolic pressure before test [mm Hg]	135.35 ± 12.37	140.5 ± 10.07	0.16
Diastolic pressure before test [mm Hg]	78.85 ± 10.87	84.3 ± 11.32	0.13
Systolic pressure after test [mm Hg]	152.85 ± 18.10	158.1 ± 18.97	0.38
Diastolic pressure after test [mm Hg]	86.4 ± 18.10	90.05 ± 13.41	0.33
HR before test [bpm]	84.65 ± 14.68	80.7 ± 16.68	0.43
HR after test [bpm]	116.4 ± 13.56	112.7 ± 15.38	0.42

TABLE 6 Percentage ability to complete all tasks during the forward reels before and after the training process in cadet pilots.

Variable	Before training Process	After training process	Significance value
Percentage ability to complete the task [%]	65.6 ± 24.51	86.4 ± 13.05	$p < 0.01$
Counting paratroopers in the same colour [%]	80 ± 0.41	90 ± 0.31	0.39
Counting cars in the same colour [%]	75 ± 0.44	95 ± 0.22	0.08
Arithmetic actions [%]	40 ± 0.50	75 ± 0.44	$p < 0.05$
Counting shapes of one type [%]	70 ± 0.47	90 ± 0.31	0.12
Counting shapes in the same colour [%]	85 ± 0.37	95 ± 0.22	0.30
Synthetic memory test [%]	50 ± 0.51	75 ± 0.44	0.11
Number of completed reels	32.55 ± 21.97	40.2 ± 20.06	0.26

significant increase in the correctness of arithmetical actions was observed in the second test in relation to the first one (with $p < 0.05$). It was shown that the remaining tasks and the number of completed reels in the second test improved, but they were not statistically significant (Table 6).

The results indicate many statistically significant changes in the relationships before and after the training process (Table 7 and Table 8). In the first test (before the training process), it was shown that the number of reels performed correlates negatively and statistically significant with age (at $p < 0.01$) and positively with the percentage ability to perform all tasks during the test (at $p < 0.05$). The percentage ability to perform all tasks in the test positively correlates with three tasks included: counting paratroopers in one colour (with $p < 0.05$), arithmetic actions (with $p < 0.01$), as well as counting shapes of one type (with $p < 0.01$). Moreover, it positively correlates with the number of reels made forward (with $p < 0.05$) and negatively with age (with $p < 0.05$). The task of counting paratroopers in the same colour showed a statistically significant negative correlation with age (with $p < 0.01$) and a positive correlation with the percentage ability to perform all tasks during the test (with $p < 0.05$) and counting shapes of one type (with $p < 0.05$). The arithmetic task showed a significant positive correlation with the diastolic pressure measured before the test (with $p < 0.01$). The task consisting in counting shapes of one type

TABLE 7 Correlations between age. Hemodynamic ratios. Number of reels and individual test tasks before the training process.

Variable	1	2	3	4	5	6	7	8
1	X							
2	$r = 0.45$ $p < 0.05$	X						
3	$r = 0.37$ $p = 0.11$	$r = 0.50$ $p < 0.05$	X					
4	$r = 0.41$ $p = 0.07$	$r = 0.38$ $p = 0.10$	$r = 0.29$ $p = 0.22$	X				
5	$r = 0.17$ $p = 0.47$	$r = 0.67$ $p < 0.01$	$r = 0.15$ $p = 0.52$	$r = 0.24$ $p = 0.32$	X			
6	$r = 0.35$ $p = 0.13$	$r = 0.74$ $p < 0.01$	$r = 0.49$ $p < 0.05$	$r = -0.13$ $p = 0.60$	$r = 0.31$ $p = 0.18$	X		
7	$r = 0.29$ $p = 0.21$	$r = 0.37$ $p = 0.10$	$r = 0.14$ $p = 0.56$	$r = 0.08$ $p = 0.74$	$r = 0.06$ $p = 0.81$	$r = 0.34$ $p = 0.15$	X	
8	$r = 0.03$ $p = 0.91$	$r = 0.39$ $p = 0.09$	$r = -0.25$ $p = 0.29$	$r = -0.12$ $p = 0.63$	$r = 0.20$ $p = 0.39$	$r = 0.22$ $p = 0.36$	$r = -0.14$ $p = 0.56$	X
9	$r = -0.57$ $p < 0.01$	$r = -0.51$ $p < 0.05$	$r = -0.67$ $p < 0.01$	$r = -0.20$ $p = 0.39$	$r = 0.06$ $p = 0.81$	$r = -0.57$ $p < 0.01$	$r = -0.49$ $p < 0.05$	$r = 0.08$ $p = 0.74$
10	$r = -0.15$ $p = 0.52$	$r = 0.15$ $p = 0.51$	$r = -0.19$ $p = 0.41$	$r = -0.34$ $p = 0.14$	$r = 0.37$ $p = 0.11$	$r = 0.18$ $p = 0.44$	$r = 0.49$ $p < 0.05$	$r = 0.04$ $p = 0.88$
11	$r = -0.15$ $p = 0.54$	$r = 0.33$ $p = 0.15$	$r = 0.12$ $p = 0.61$	$r = 0.01$ $p = 0.96$	$r = 0.62$ $p < 0.01$	$r = 0.12$ $p = 0.60$	$r = 0.14$ $p = 0.56$	$r = -0.03$ $p = 0.89$
12	$r = 0.19$ $p = 0.42$	$r = 0.34$ $p = 0.15$	$r = -0.01$ $p = 0.96$	$r = -0.17$ $p = 0.48$	$r = 0.30$ $p = 0.20$	$r = 0.20$ $p = 0.39$	$r = 0.15$ $p = 0.54$	$r = 0.60$ $p < 0.01$
13	$r = 0.29$ $p = 0.22$	$r = 0.21$ $p = 0.38$	$r = -0.06$ $p = 0.81$	$r = 0.12$ $p = 0.61$	$r = 0.18$ $p = 0.44$	$r = 0.11$ $p = 0.65$	$r = 0.40$ $p = 0.08$	$r = 0.02$ $p = 0.93$
14	$r = -0.23$ $p = 0.32$	$r = 0.36$ $p = 0.12$	$r = -0.07$ $p = 0.76$	$r = -0.22$ $p = 0.34$	$r = 0.33$ $p = 0.16$	$r = 0.30$ $p = 0.19$	$r = 0.13$ $p = 0.59$	$r = 0.45$ $p < 0.05$
15	$r = 0.40$ $p = 0.08$	$r = 0.41$ $p = 0.07$	$r = 0.39$ $p = 0.09$	$r = 0.43$ $p = 0.06$	$r = 0.11$ $p = 0.63$	$r = 0.19$ $p = 0.42$	$r = -0.01$ $p = 0.97$	$r = 0.18$ $p = 0.44$

1, Number of completed reels; 2, Percentage ability to complete the task; 3, Counting paratroopers in the same colour; 4, Counting cars in the same colour; 5, Arithmetic actions; 6, Counting shapes of one type; 7, Counting shapes in the same colour; 8, Synthetic memory test; 9, Age; 10, Systolic pressure before test; 11, Diastolic pressure before test; 12, Systolic pressure after test; 13, Diastolic pressure after test; 14, HR before test; 15, HR after test; *r*, Correlation value; *p*, Significance value.

TABLE 8 Correlations between age, hemodynamic ratios, number of reels and individual test tasks after the training process.

Variable	1	2	3	4	5	6	7	8
1	X							
2	$r = 0.33$ $p = 0.15$	X						
3	$r = 0.23$ $p = 0.34$	$r = 0.31$ $p = 0.18$	X					
4	$r = 0.19$ $p = 0.42$	$r = 0.37$ $p = 0.11$	$r = -0.08$ $p = 0.75$	X				
5	$r = 0.12$ $p = 0.62$	$r = 0.31$ $p = 0.19$	$r = -0.19$ $p = 0.42$	$r = -0.13$ $p = 0.58$	X			
6	$r = 0.15$ $p = 0.53$	$r = 0.53$ $p < 0.05$	$r = -0.11$ $p = 0.64$	$r = -0.08$ $p = 0.75$	$r = 0.19$ $p = 0.42$	X		
7	$r = 0.19$ $p = 0.42$	$r = 0.37$ $p = 0.11$	$r = -0.08$ $p = 0.75$	$r = 1.00$ $p = ---$	$r = -0.13$ $p = 0.58$	$r = -0.08$ $p = 0.75$	X	
8	$r = 0.01$ $p = 0.98$	$r = 0.46$ $p < 0.05$	$r = 0.19$ $p = 0.42$	$r = -0.13$ $p = 0.58$	$r = -0.33$ $p = 0.15$	$r = 0.19$ $p = 0.42$	$r = -0.01$ $p = 0.58$	X
9	$r = -0.50$ $p < 0.05$	$r = -0.19$ $p = 0.42$	$r = -0.35$ $p = 0.13$	$r = 0.13$ $p = 0.58$	$r = 0.19$ $p = 0.41$	$r = -0.11$ $p = 0.65$	$r = 0.13$ $p = 0.58$	$r = -0.34$ $p = 0.14$
10	$r = -0.24$ $p = 0.30$	$r = -0.16$ $p = 0.49$	$r = -0.41$ $p = 0.07$	$r = 0.11$ $p = 0.66$	$r = 0.06$ $p = 0.786$	$r = -0.37$ $p = 0.11$	$r = 0.11$ $p = 0.66$	$r = 0.09$ $p = 0.71$
11	$r = -0.20$ $p = 0.39$	$r = -0.30$ $p = 0.20$	$r = -0.29$ $p = 0.21$	$r = 0.01$ $p = 0.98$	$r = -0.15$ $p = 0.52$	$r = -0.40$ $p = 0.08$	$r = 0.01$ $p = 0.98$	$r = 0.11$ $p = 0.45$
12	$r = -0.05$ $p = 0.82$	$r = 0.26$ $p = 0.27$	$r = -0.06$ $p = 0.78$	$r = 0.44$ $p = 0.06$	$r = -0.02$ $p = 0.95$	$r = 0.22$ $p = 0.36$	$r = 0.44$ $p = 0.06$	$r = -0.08$ $p = 0.72$
13	$r = -0.07$ $p = 0.79$	$r = -0.16$ $p = 0.49$	$r = 0.12$ $p = 0.63$	$r = 0.07$ $p = 0.77$	$r = -0.17$ $p = 0.46$	$r = 0.01$ $p = 0.95$	$r = 0.07$ $p = 0.77$	$r = -0.27$ $p = 0.25$
14	$r = 0.28$ $p = 0.22$	$r = 0.10$ $p = 0.69$	$r = -0.09$ $p = 0.71$	$r = 0.09$ $p = 0.69$	$r = 0.02$ $p = 0.92$	$r = 0.07$ $p = 0.78$	$r = 0.09$ $p = 0.69$	$r = 0.06$ $p = 0.80$
15	$r = 0.17$ $p = 0.48$	$r = 0.17$ $p = 0.49$	$r = 0.26$ $p = 0.27$	$r = -0.23$ $p = 0.32$	$r = -0.13$ $p = 0.59$	$r = 0.13$ $p = 0.59$	$r = -0.23$ $p = 0.32$	$r = 0.38$ $p = 0.10$

1, Number of completed reels; 2, Percentage ability to complete the task; 3, Counting paratroopers in the same colour; 4, Counting cars in the same colour; 5, Arithmetic actions; 6, Counting shapes of one type; 7, Counting shapes in the same colour; 8, Synthetic memory test; 9, Age; 10, Systolic pressure before test; 11, Diastolic pressure before test; 12, Systolic pressure after test; 13, Diastolic pressure after test; 14, HR before test; 15, HR after test; *r*, Correlation value; *p*, Significance value.

showed a positive correlation with the percentage ability to perform all tasks (with $p < 0.01$) and counting paratroopers of the same color (with $p < 0.05$) and negative correlation with age (with $p < 0.01$). Synthetic memory test showed a positive, statistically significant correlation with systolic pressure after the test (with $p < 0.01$) and heart rate before the test (with $p < 0.05$). The age of the respondents showed a statistically significant negative correlation with the number of completed reels (with $p < 0.01$), the percentage ability to perform all tasks during the test (with $p < 0.05$), as well as the tasks consisting of counting one type of shapes (with $p < 0.01$) and counting shapes of the same colour (with $p < 0.05$).

The results obtained during the second test (after the end of the training process) showed a negative, statistically significant correlation between the number of reels made and age (at $p < 0.05$; Table 8). A statistically significant positive correlation was observed between the percentage ability to complete all tasks and counting one type of shape (with $p < 0.05$) and a synthetic memory test (with $p < 0.05$; Table 8). It was found that the percentage ability to complete all tasks occurs in the same correlation with shape counting as before the training process, but it is at a lower statistical significance level. The other variables showed no statistically significant correlation (Table 8).

Discussion

On the basis of the results obtained in the sample after the training process (test II), an increase in physical skills was found in the number of completed reels, an increase in correct answers in tasks such as: counting parachutists in the same colour, counting cars in the same colour, counting shapes of one type, counting shapes of the same colour, synthetic memory test and an increase in the values of indicators such as age, systolic and diastolic pressure before and after the test, heart rate before and after the test, compared to the pre-training period (test I), but not statistically significant. However, a statistically significant difference was found in the percentage of ability to perform all tasks and in the task of arithmetic operations. It follows that the percentage ability to complete all tasks is closely related to the number of completed reels. It was observed from the course of the tests that the respondents performing a larger number of reels made more mistakes in answering the questions asked in the central field of vision. With a smaller number of completed reels, they achieved a higher percentage of ability to complete all tasks. The reason for the feedback between the number of reels and the percentage ability to complete all tasks during the test is the specificity of the reels performed on the looping. During these exercises, there are positive +Gz (head - legs direction) and negative -Gz (head - legs direction) accelerations in the tested body, which may contribute to lower efficiency in answering the questions. Similar conclusions were made in tests, carried out using a human centrifuge, concerning the acceleration tolerance level. It has been shown that an increased level of loading causes a delay in response time and a delay in response to visual stimuli (Truszczynski et al., 2014). The results obtained by the subjects depend on the rate of fatigue during exercise and the level of exercise adaptation. Taking into account the results obtained by the respondents in the number of completed reels on the looping and the percentage ability to complete the task [%], it can be concluded that the completed training process increased their level of psychomotor performance, as evidenced by the value of the Cohen's test effect (Table 4).

The tests showed an increase in the number of completed reels and the percentage of ability to complete all tasks. This shows a higher level of psychomotority, after the training process on SAGI, compared to test I. The improvement of psychomotority is achieved by means of two subsystems - motor and sensory (Lisowski and Mihuta, 2013). As a result of the training process the level of integration of the subsystems increased. Barron and Rose (2017) showed that pilots with a higher level of multitasking achieve higher performance in flight (tested by math tasks, memorizing and monitoring). They recommended multitasking as a predictor for the selection of future military pilots. This is confirmed by a significant correlation showed in authors study between the percentage ability to complete all tasks and the number of completed reels in test I and the lack of statistical significance in test II, which is characterised by higher results in both the number of completed reels and the percentage ability to complete all tasks (psychomotor level). This may be explained by the fact that a decrease in the correlation value (feedback) between the two subsystems in test II is associated with an increase in the level of psychomotority and the level of multitasking of the tested, cadet - pilots.

In these tests, it is interesting to note that age shows significant correlations in both test I and test II. In test I with the number of completed reels, the percentage ability to perform all tasks during the test and the tasks included in the test, such as counting parachutists in the same colour, counting shapes of one type and counting shapes of the same colour. In test II, it shows a correlation only with the number of reels and it is at a lower level of significance, which may indicate an increase in psychomotor skills despite the increase in age. In the previous studies it has been proved many times that the level of psychomotor skills is strongly related to age and the level of difficulty of tasks performed (Armbruester et al., 2007; Sutter and Oehl, 2010; Tan and Sun, 2021). Considering the identical training process and the same conditions of everyday functioning of the test persons, these results indicate a positive effect of the training programme on SAGI on the level of psychomotor skills.

The percentage ability to perform all tasks during test I was significantly correlated with its components, such as counting paratroopers of the same colour, arithmetic activities and counting shapes of one type. In test II, significance was demonstrated with counting of one type of shapes and a synthetic memory test. What is important, attention should be paid to the decrease in the number of statistically significant correlations and their level of significance in test II, as compared to test I. This may indicate an increase in the level of psychomotority, which results in a decrease in the influence of individual components on the percentage ability to perform all tasks. It should be emphasized that the test persons in tests I and test II performed physical effort in the zone of aerobic metabolism, as evidenced by HR values. Also noteworthy is the pre-exercise increase in blood pressure. This may be due to pre-exercise stress and lack of knowledge of the training device (test I) and the desire to improve the previously obtained result (test II). The higher blood pressure found at the end of test II may be due to an increase in the number of reels, which may be associated with a longer effect of this exercise on blood system receptors. Similar indicators were analyzed in studies on performing various tasks on aviation simulators. These studies showed that heart rate and blood pressure levels are influenced by the difficulty level of the pilot's task. In addition, the difficulty of the tasks and the amount of visual information causes a decrease in the number of movements (blinking eyes) and their duration. It has been demonstrated that mental effort increases arterial pressure and heart rate (Veltman and Gaillard, 1996). Similar conclusions were reached by Leino et al. (1999), analyzing neuroendocrine responses and psychomotority in the selection process of candidates for military pilots. Comparing the test procedure to an air mission, they proved that it is characterized by a high level of mental strain. Moreover, they showed that low neuroendocrine responses in the psychomotor test were associated

with good stress tolerance. It is important, however, that both these tests, unlike ours, were not characterized by physical strain. These studies show that raising blood pressure is not only the result of physical effort, but it can also be raised by mental strain.

So far, pilots were tested before and after the training process was completed, however, in resting conditions (without connection with physical exercise; Leino et al., 1999; Russo et al., 2005; Tomczak, 2015; Tomczak et al., 2017). The authors of these studies have demonstrated that their tests have diagnostic value in terms of physical and mental skills under normal and extreme working conditions of a military pilot. Realization an aerial mission in extreme conditions for a long time may lead to disorder motor skills. That observations were made by Tomczak et al. (2019) on the soldiers of the Polish Army. Therefore, the authors believe that for military pilots, the psychological test should be performed under strain conditions.

Based on the results of the tests, it has been shown that the training program on SAGI has a great influence on increasing psychomotor skills in cadet pilots. The diagnostic and training device used during the looping test gave an opportunity to assess attention concentration, reaction and psychophysical condition under extreme environmental conditions. The test combined with a diagnostic and training device was found to be highly useful in the process of special pilot training.

Moreover, the conducted pilot studies will be helpful in assessing future studies that will be carried out before and after aviation practices in the air. As a reference point, it will allow to assess the impact of stress occurring in conditions of real flight in pilots on the level of them psychomotoricity. Comparing the speed of response to the questions (stimulus) and the speed of execution of reels on forward on looping in a limited time can provide valuable guidance for practical use in pilot training.

Conclusion

The authors found that a special training process on SAGI had a positive effect on the level of psychomotority in cadet pilots, by increasing the percentage of the task capacity measured by the diagnostic and training device and the number of reels performed in the test after the training process (test II) compared to the test before the training process (test I). After the training process (test II), a reduction in the positive correlation between the ability to perform tasks [%] and the number of forward turns on looping compared to test I was found. According to the size of the Cohen' d effect the training process influenced at psychomotor skills and percentage ability to complete the task at high level improved.

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 researchers have obtained the consent of the Bioethics Committee, at the Medical University of Poznań, issued on 15 May 2019 with the number 610/19. The patients/participants provided their written informed consent to participate in this study.

Author contributions

AP and ZW contributed to conception and design of the study. AP organized the database. AP and ZW performed the statistical analysis. AP wrote the first draft of the manuscript. AP wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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.

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Understanding the complexity of provincial-level elite sport policy change: The case of Shanghai municipality

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The analysis of elite sport policy changes at the provincial level remains relatively uncharted territory despite the substantial contributions of provincial-level elite sport to national elite sport success. Data were gathered from semistructured face-to-face interviews and official and semiofficial documents. The key findings were that (1) Guangdong, as a provincial compatriot of Shanghai, has made tremendous efforts and obtained notable achievements in professional football and thus serves as a powerful stimulant for policy reform regarding elite sports in Shanghai; (2) the policy stream has been strengthened by knowledge-based (epistemic) communities at the Shanghai University of Sports that can examine cause and effect relationships and further propose specific policies; and (3) the general director of the Shanghai Administration of Sports plays a central role in advocating for policy proposals. The current research offers practical insights into strategies for reviewing policy trajectories to enhance policy design and implementation.

KEYWORDS

elite sport, sport policy, policy change, provincial level, multiple streams framework

Introduction

Elite sport success has become an '*irresistible priority*' in countries around the world since at least the mid-1960s (Green and Houlihan, 2005). Engulfed by the tide of the '*global sporting arms race*' (Oakley and Green, 2001), elite sport has consistently attracted mainstream policy attention, and policy researchers agree that elite sport success can actually be developed (Grix and Carmichael, 2012; De Bosscher et al., 2015; Zheng and Chen, 2016). Despite the plethora of studies on the static analysis of elite sport policy at the national level (Digel et al., 2003; Green and Houlihan, 2005; Houlihan and Green, 2008) and the growing research attention given to the dynamic analysis of elite sport policy change (Peng et al., 2019; Camargo et al., 2020; Zheng and Liu, 2020), there is a dearth of analysis of elite sport policy and policy change at the provincial level.

This lacuna is surprising considering the substantial support for provincial-level sport organizations and their contributions to elite sport success (Green and Houlihan, 2005; Yamamoto, 2008; Girginov, 2016; Zheng et al., 2018b). Furthermore, the essential role of provincial-level elite sport is described by De Bosscher et al. (2015) as '*horizontal coordination at the national level*' and, equally important, '*vertical coordination between the*

national policy level and provincials'. In summary, the lack of provincial-level elements in the elite sport policy literature clearly reflects a significant gap in extant elite sport policy research.

China has made great strides in medal tallies at the Summer Olympic Games, with a particularly impressive upswing in gold medals (Brownell, 2008; Tan and Houlihan, 2012; Zheng and Chen, 2016). Sport policy in China examines many themes, including sport for all, professional sport, elite sport, and sport mega events (Zheng et al., 2019). A related recurring question among sport governance and policy researchers is how to analyse and understand Chinese elite sport policy at the national level (Brownell, 2008; Tan and Bairner, 2010; Tan and Houlihan, 2012; Hu and Henry, 2017). Additionally, the first-level administrative divisions (e.g., provinces) have routinely updated their elite sport policy to maintain China's competitive advantage in these intense medal competitions. It is against this background that the focal policy for this research was planned. On June 6, 2019, the Shanghai Municipal Government (SMG) issued the '*Constructing the New Developmental System of Shanghai Elite Sport*' policy (Shanghai Municipal Government, 2019). This provincial-level elite sport policy is widely considered a general blueprint for the reform of the Shanghai elite sport system.

Hence, this article rests on a case study of Shanghai Municipality, which has not been previously examined by scholars, and fills the abovementioned gap by answering the following research question: How can elite sport policy change in Shanghai Municipality be analysed and understood? Furthermore, in response to Houlihan et al.'s (2009) criticism that meso-level theory is underutilized in studies aiming to advance the understanding of the processes of sport policy making and reform, this research employed the Multiple Streams Framework (MSF) model to fulfil the historical policy narrative of Shanghai elite sport. Subsidiary issues that still need to be clarified to answer the principal research question include the following: What do the problem, policy and political streams contain? Who has played the role of policy entrepreneur?

The remainder of this paper is structured as follows. The next section reviews the literature on Chinese elite sport policy at the national level, the interorganizational relationship literature focusing on provincial-level sport organizations and the MSF put forth by Kingdon (1984). The subsequent methodological section primarily clarifies the research design and the corresponding data collection process. The fourth section presents the main findings. The last section discusses the critical findings, introduces the study's limitations, and summarizes the research.

Literature review and theoretical framework

Chinese elite sport policy at the national level

Research on China has always noted the contrast between the country's '*policy rhetoric*' and '*on-the-ground reality*' (Yu, 2009). In sport-specific analyses, '*sport for all*' has often been deliberately ignored in favour of elite sport, even though there is a long-standing policy rhetoric aimed at achieving an equilibrium between the two (Zheng et al., 2019). The concept '*Juguo Tizhi*', which can be interpreted as both national and subnational organizations mobilizing their finite resources to bolster elite sport success, emerged following the Sydney 2000 Summer Olympic Games (Brownell, 2008; Hu and Henry, 2017). The enactment of the '*Olympic Strategy*' further legitimized the superior status of elite sport over '*sport for all*' (Zheng et al., 2018a). Furthermore, from the 1990s to 2010s, there were three editions of '*The Outline of the Strategic Olympic Glory Plan*', which steered the progress of elite sport across these three decades (Zheng et al., 2018a; Ma and Kurscheidt, 2019). At a critical juncture (i.e., Beijing's successful Olympic bid), in addition to a basic policy document (i.e., *The Outline of the Strategic Olympic Glory Plan: 2001–2010*), a specific policy titled '*The 2008 Olympic Glory Action Plan*' was promulgated, highlighting the central government's pursuit of success on its home soil (Zheng et al., 2018a).

The aforementioned policies to some extent delineate the centralized model of sport governance in China, specifically regarding Olympic elite sport. With the transition from the planned economy era to the reform and opening-up era, Chinese elite sport governance began diverging along two paths of logic: the centralized model of Olympic elite sport and the more liberal and commercialized model of professional football (Zheng et al., 2018a; Xiong and Ma, 2021). This divergence was triggered by an exogenous policy prioritization of '*low investment and high return*' sports or disciplines rather than an endogenous change in market structures (Ma and Kurscheidt, 2020). However, the two logics no longer diverge. Chinese football authorities now seem to be employing a gradualist approach to institutional reform, which greatly facilitates commercialization. To date, only incremental reform at the club governance level has been undertaken (Ma and Zheng, 2022).

Provincial-level elite sport studies from the interorganizational relationship literature

The existing elite sport policy literature lacks an emphasis on provincial-level elite sport policy (change), even though provincial-level elite sport is regarded as the '*backbone and core*' for delivering elite sport success within the Chinese context (Zheng et al., 2018b). However, this does not mean that there is no concrete research on elite sport development at the provincial level within the Chinese context. Notably, Zheng et al. (2018b) specifically explored interorganizational conflict between national and subnational (provincial) sport organizations in China using three case studies (artistic gymnastics, swimming, and cycling). The study uncovered crucial interorganizational conflicts among national and provincial sport organizations within China's top-down bureaucratic elite sport logic. Moreover, Ma and Kurscheidt's (2019) research evaluated the effectiveness of the

National Games of China (NGC) in the coordination of public sport governing bodies at the national and provincial levels. The NGC's character as a 'governance instrument' was interpreted in depth through a socioeconomic institutional approach. Despite its relative importance, this line of research provides only limited insights into the policy making of provincial-level elite sport. To date, no in-depth study has examined the policy making process of provincial-level elite sport in the Chinese context. The current research explored the multiple factors influencing the policy making process under the guidance of the MSF.

Multiple streams framework

De Bosscher et al. (2015) argued that international sporting success is determined by factors at three levels: macro (environment), meso (policy) and micro (talent). A similar point can be made in relation to public policy. It has been suggested that the theoretical realm of public policy can also be categorized into three levels: the macro-, meso-, and micro (Houlihan, 2005). Macrolevel public policy theories refer to the fundamental nature of social and political structures (e.g., pluralism, neopluralism, and elite theory), whereas microlevel policy examines specific decisions or organizations (Houlihan, 2005; Zheng et al., 2018a). Consistent with the central point of this article on elite sport policy changes in Shanghai, it could be argued that the macro- and microlevels are either too broad or too narrow. The mesolevel serves as a heuristic analytical lens that can fulfil the aim of this research, echoing Zheng et al.'s (2018a, 12) assertion that public policy theory at the mesolevel (e.g., the advocacy coalition framework, punctuated equilibrium theory, MSF) is more operational and manageable than that at other levels.

It is worth noting that MSF is one of the most convincing theoretical underpinnings for understanding the crucial timing or juncture of a policy change (Zahariadis, 2007; Weiner, 2011; Baumgartner, 2016). The MSF was developed by Kingdon (1984) to understand the domestic agenda and was derived from the '*garbage can*' model proposed by Cohen et al. (1972), who emphasized '*the anarchical nature of organizations and the policy process*' (Houlihan, 2005). The '*garbage can*' metaphor was further clarified by Cohen et al. (1972) as '*various kinds of problems and solutions [being] dumped by participants as they are generated*'. Kingdon (1984, 1995) identified three largely separate streams flowing through the system: the problem stream, the policy stream, and the political stream. These three streams, together with policy windows and policy entrepreneurs, constitute the five structural components of the MSF (Kingdon, 1984, 1995).

The problem stream primarily addresses the specific issues that governments address and attempt to resolve. These problems are not always identifiable (Peng et al., 2019), but government policymakers generally identify problems *via* three approaches: indicators, focusing events, and feedback on the effectiveness of existing policies (Houlihan, 2005). First, indicators refer to the assessment of the severity of a problem. In the elite sport policy area, the decline in the number of gold medals at the Summer Olympic Games rendered the problem visible. Second, focusing events, notably crises or disasters, draw governments' attention to detailed issues. Finally, problems can also be identified through feedback on the performance of current policies (Houlihan and Lindsay, 2013; Salisbury, 2016).

Analogous to '*primeval soup*' (Parsons, 1995), the term policy stream refers to '*ideas, backed by particular policy communities, float around and occasionally combine and rise to the top of the agenda*' (Houlihan, 2005, 171). The process by which ideas compete for acceptance and legitimacy is akin to that of natural selection. Selected and accepted policy ideas may rise to the top of the agenda, while the rest remain at the bottom (Wu, 2021). In addition, two criteria influence why some ideas gain prominence and others are neglected: technical feasibility and value acceptability (Zheng et al., 2018a, 27). The latter refers to consistency with the community's dominant values (Houlihan, 2005).

The political stream basically includes three components: the national mood, organized political forces, and the government. In line with Zahariadis (2007, 73), the national mood can be conceptualized as '*a fairly large number of individuals in a given country tend[ing] to think along common lines and… the mood swing[ing] from time to time*'. The second influencer proposed by Kingdon (1984, 1995) is organized political forces, such as parties and interest and pressure groups. It is worth noting that the second influencer is less likely to actualize in the Chinese context, which is characterized by a one-party political system (Peng et al., 2019, 5). Furthermore, echoing Zahariadis's (2007) argument, the national mood and the third influencer (i.e., government) are highly likely to influence government agendas. The last influencer is defined as the key personnel and structural changes within the government (Zahariadis, 2007; Zheng and Liu, 2020).

Policy windows provide chances for proponents to initiate action to advocate for their selected ideas or draw attention to specific issues (Wu, 2021). Kingdon (1984, 1995) identified two types of policy windows, namely, problem windows and political windows. This classification indicates the unfolding mechanisms of a policy window that can be facilitated by a problem stream or a political stream. Moreover, although the three streams are largely separate, they can merge at critical junctures. In line with Parsons's (1995, 194) conclusion, '*if all three streams are joined then the item has a high probability of reaching the top of the decision agenda*'.

The abovementioned coincidence of the three streams requires a facilitator (Zheng et al., 2019) or a broker (Ackrill and Kay, 2011) to sell the ideas or proposals to policy makers. Policy entrepreneurs are '*advocates who are willing to invest their resources to promote a position in return for anticipated future gain in the form of material, purposive, or solidary benefits*' (Kingdon, 1984, 1995). Policy windows are of short duration, and policy entrepreneurs feel obliged to make the most of the hard-earned opportunity to advocate for their agenda. The indefatigability of policy entrepreneurs as advocates is underlined. The success of policy entrepreneurs relies significantly on their capacity to look

for relevant policy makers who are receptive to their intentionally selected proposals (Salisbury, 2016).

As a major theoretical breakthrough in the study of public policy (Sabatier, 1999), the application of the MSF has grown considerably in recent years in terms of geographical and cultural spread (e.g., Chalip, 1996; Richardson, 2001; Travis and Zahariadis, 2002; Teodorovic, 2008; Lancaster et al., 2012). Its effectiveness in the Chinese context has been fully proven by, for instance, policy-making studies on the Chinese detention and repatriation system (Zhu, 2008) and on Chinese college matriculation (Zhou and Feng, 2014). More specifically, in relation to sport policy analysis in the Chinese context, MSF's applicability has also been demonstrated, as exemplified by studies focused on Chinese elite swimming policy changes between 2000 and 2012 (Zheng, 2017), the analysis of the Chinese football reform of 2015 (Peng et al., 2019), and policy analysis of elite sport development in Hong Kong (Wu, 2021). In summary, the MSF can be perceived as a useful theoretical perspective for analysing Shanghai's elite sport policy.

Research methods

Research paradigm and research design

The research paradigm was conceptualized by Bailey (1994, 26) as '*the metal window through which the researcher views the world*'. It exerts considerable influence on the researcher's thinking regarding the world and his or her interpretation of social phenomena (Grix, 2010; Wu, 2021). This research followed the 'critical realist' approach put forth by Bhaskar (1989). Different from realists' assertion that social phenomena have objective attributes and exist outside of human influence (Bryman, 2016) and from constructivists' argument that social phenomena and their corresponding meanings are constantly being performed by social actors (Bryman, 2016), critical realists' position occupies a middle ground on this spectrum, with realists at one end and constructivists at the other, advocating that the social world can be understood only by recognizing the structures that call into being events and discourses, and the identification of the structures can be fulfilled only by means of the practical and theoretical work of the social sciences (Bhaskar, 1989).

Hence, critical realism argues that social facts need to be objectively reflected. Nevertheless, since not all social facts can be observed and quantified, it is critical to embrace the subjective element. According to Guba and Lincoln (1994), knowledge of the subject under investigation (i.e., elite sport policy change at the provincial level) is believed to exist but is only '*imperfectly apprehendable because of basically flawed human intellectual mechanisms and the fundamentally intractable nature of phenomena*'. Therefore, this study employed a qualitative strategy, counting on '*nonnumerical analysis to provide understanding*' (Gratton and Jones, 2010).

This research primarily used a single-case study design (Yin, 2009). The MSF is used to structure a case study of the 2019 Shanghai elite sport policy reform. In line with the argument of Travis and Zahariadis (2002, 495), MSF researchers adopt qualitative case study approaches in a typical manner, and Kingdon's work has rarely been used in quantitative studies. Three criteria for case selection reveal why the research focuses on Shanghai Municipality: This case is significant (Denscombe, 2007) and representative (Stake, 1995) or exemplifying (Bryman, 2016) and presents a convenient and feasible study object (Denscombe, 2007). Shanghai, as the economic centre of the People's Republic of China (PRC), occupies an indispensable position within the Chinese elite sport landscape, as strongly evidenced by the fact that Yao Ming, who has been hailed as '*an icon of confidence for China*' (Xu, 2008, 210), and Liu Xiang, who brought the PRC its first Olympic gold medal in men's track and field, both came from Shanghai. In addition, the case selection was facilitated by the researchers' connections within the Shanghai elite sport system, ability to speak both Chinese and English, and strong knowledge of official and semiofficial document sources.

Notably, this research does not endeavour to offer an '*all-powerful formula*' (Zheng et al., 2018b), '*one-size-fits-all*' solution (Cloete and De Coning, 2016) or '*silver bullet*' (Wu, 2021) that is useful to all nations or regions. Instead, it focuses on 'thick description' (Tracy, 2010) in the context of Shanghai Municipality, which is in line with the argument that contextual uniqueness is an inherent feature of social phenomena and accompanying qualitative research (Shenton, 2004; Tan et al., 2019). Therefore, audiences both within and outside academia are encouraged to evaluate the transferability of the results based on their specific situations in a critical manner.

Data collection

This study adopted a qualitative method. Considering the value of primary interview data (Miller and Sinanan, 2014), semistructured face-to-face interviews were conducted even though the COVID-19 outbreak was spreading. This is because in mainstream Chinese culture, in the minds of elderly and middle-aged persons, non-face-to-face interviews are impolite and make them reluctant to share their thoughts. Using *a 'judgemental sampling strategy*' (Blaikie, 2010) or '*purposive sampling strategy*' (Abrams, 2010), first-hand materials from related stakeholders were collected. Table 1 presents details (alias, organization and position) on the four interviewees.

All interviewees were informed about the essence of the research, a process that drew upon a translated Chinese version of an ethics checklist and included soliciting the participants' signed informed consent. Generally, the interview protocol employed in this study was tightly focused on the research question mentioned in the introduction section. The semistructured face-to-face interviews lasted between 30 min and 1 h each.

TABLE 1 Profiles of the interviewees.

Interviewee ID	Age	Organization	Position
A	38	Shanghai Administration of Sports	Deputy director responsible for elite sport
B	35	Sports Bureau of Yangpu District	Director responsible for elite sport training
C	59	Shanghai University of Sport	Professor specializing in elite sport
D	43	Shanghai University of Sport	Professor specializing in sport policy

Perceived as '*windows onto social and organizational realities*' (Bryman, 2016), relevant official and semiofficial documents supplement the semistructured interviews. Official (e.g., from the Shanghai Administration of Sports and Shanghai University of Sport) and semiofficial (e.g., from the websites of Oriental Sports Daily and Great Sports) documents were collected for secondhand data. Additionally, peer-reviewed academic articles in Mandarin from the Chinese National Knowledge Infrastructure, i.e., the Chinese version of the Web of Science, were examined.

Data analysis and trustworthiness

The discrepancies between official and semiofficial documents and the collected interview transcripts were scrupulously cross-checked. The interview transcripts were carefully examined to resolve any inconsistencies with audio recordings. Then, the interview transcripts were shared with the corresponding interviewees for further validation (Braun and Clarke, 2006; Burke, 2016). With regard to the non-English data, back translation was used to guarantee the data quality. The thematic analysis approach was used to fix the qualitative data (Boyatzis, 1998; Guest et al., 2011). More specifically, on the one hand, deductive coding processes and theme identification were achieved in accordance with the well-defined fundamental elements of the MSF (Ryan and Bernard, 2003); on the other hand, inductive coding approaches focused on the codes derived directly from the data, enabling me to interpret phenomena that could not be explained by existing theories or concepts (Miles and Huberman, 1994; Fereday and Muir-Cochrane, 2006).

Findings

Problem stream

As the first structural element of the MSF, the problem stream was conceptualized as the underlying rationale that the government followed to launch the policy change. In line with the MSF put forth by Kingdon (1984, 1995), three factors were considered to identify problems: focusing events and crises (e.g., poor performance), indicators, and feedback on the effectiveness of existing policies. Regarding the '*focusing events and crises*', a director inside the Sports Bureau of Yangpu District made the following comment:

Everyone within the elite sport system knows that the NGC is the most important sport event in domestic China. Actually, it is a platform in which every province 'fights' or competes with each other, signalling its economic and cultural power. Unfortunately, the sporting performance of Shanghai at the NGC cannot match its role as an economic pioneer in domestic China (Interviewee B).

As presented in the literature review section, the NGC is widely considered the '*Olympic Games of China*', mainly due to its identical format to the Olympic Games and its prominent national status (Ma and Kurscheidt, 2019). In essence, the NGC can be regarded as a concrete platform for first-level administrative divisions to compete with each other (Zheng et al., 2018b). The Shanghai delegation has not ranked in the top two in the medal tally since the 9th NGC. The sporting performance of the Shanghai delegation within the NGC platform has been continually criticized for its mismatch with its role as an economic pioneer (Miao, 2012, 2013). Furthermore, the acquisition of medals heavily relies on the introduction of elite athletes from other provinces. A market mechanism, i.e., a pricing of talent, was introduced into the elite sport system following a top-down logic (Ma and Kurscheidt, 2019). In terms of '*indicators*', this mechanism can be applied to assess the magnitude of change in the hope of catching official attention (Travis and Zahariadis, 2002). At the 9th NGC, 14% of all gold medals obtained by the Shanghai delegation were won by elite athletes from other countries (Miao, 2012, 2). This figure increased to 38 and 36% at the 10th and 11th NGCs, respectively (Miao, 2012, 2), and this phenomenon attracted close attention from the SMG. Interviewee A asserted the following:

SMG, to some extent, was not satisfied with our sporting performance at the NGC platform recently. It seems that we poured a large sum of money into the introduction of elite athletes from other provinces. To be honest, this is a shorter route than the usual one. This kind of shortcut will definitely exert a negative influence on the sustainability of elite sports in Shanghai (Interviewee A).

Shanghai's constantly poor performance, the mismatch between its sporting performance and its role as an economic pioneer, and the municipality's heavy reliance on the introduction of elite athletes from other provinces are identified as a source of problems. In contrast to the common belief that negative focusing events such as poor performance are more likely to facilitate policy change (Jones, 1994), this research revealed that the stunning performance of provincial compatriots was more likely to reveal the policy window, as was confirmed by Interviewee B:

Football was the first sport to be professionalized in China. The development of professional football has attracted increased attention in wider society. Guangzhou Evergrande brings great honour to Guangdong Province. The club wins the toptiered title each year from 2011 to 2017. This club was reputed as the only one

that has ever won the Asian Champions League. By stark contrast, Shanghai professional football is losing its lustre. From the standpoint of SMG, it is a big problem (Interviewee B).

The tremendous pressure exerted by provincial compatriots, i.e., Guangdong Province, was reconfirmed by document sources. Miao (2012, 2) asserted that Shanghai experiences is pained byGuangdong Province's excellent performance in professional football because the latter's impressive advancement in professional football causes Shanghai to be overshadowed. In particular, in the Asian Football Confederation (AFC) Champions League, clubs from Guangzhou managed to defeat Korean and Japanese clubs on behalf of the PRC after President Xi Jin-Ping highlighted his dreams for the country in regard to football.

With regard to the last factor, '*feedback on the effectiveness of existing policies*', Interviewee D clarified that the policy was improper for the occasion, as was also confirmed by Interviewee C.

The old elite sport policies have always stressed the crucial and indispensable role that SMG plays. It is common sense that SMG shoulders the responsibility to distribute financial and human resources. To some extent, the old elite sport policy has doubts about the involvement of social forces. However, it is absolutely crazy for the time being that we exclude social forces from the Shanghai elite sport landscape (Interviewee D).

Social progress brings a considerable increase in training expenditures and travelling costs. Currently, the training expenditures are 10 times higher than in the old days. The travelling cost is even 50 times [higher]. Elite sport has evolved into a huge burden for our government's overhead. We need to reform elite sport policy, inviting the deep involvement of social forces (Interviewee C).

In line with Zheng et al. (2019), Chinese sport policy embraces the contrast between a politically led approach as a relic of the planned economy and a market-led approach. Notably, the shortage of financial resources is more obvious in money-consuming disciplines (e.g., equestrianism and golf) and newly added Olympic disciplines (e.g., rock climbing and breakdancing; Ma and Kurscheidt, 2021) than in other disciplines. In addition, in relation to the effectiveness of existing policies, the lack of emphasis on nurturing world-famous sport stars has been noted and firmly criticized.

Oriented as an international well-known mega-city, Shanghai is obliged to nurture internationally renowned sports stars. We should not immerse ourselves in the old times when we have Yao Ming and Liu Xiang. For the time being, we have nothing. Fortunately, the SMG realized that imperative policy inference is of great importance for nurturing sports stars (Interviewee D).

To summarize, as shown in Figure 1, the problem stream comprises the following factors: focusing events and crises (the mismatch between Shanghai's sport performance and its role as an economic pioneer, the heavy reliance on the introduction of elite athletes from other provinces, and the stunning performance of provincial compatriots), indicators (a large percentage of the total

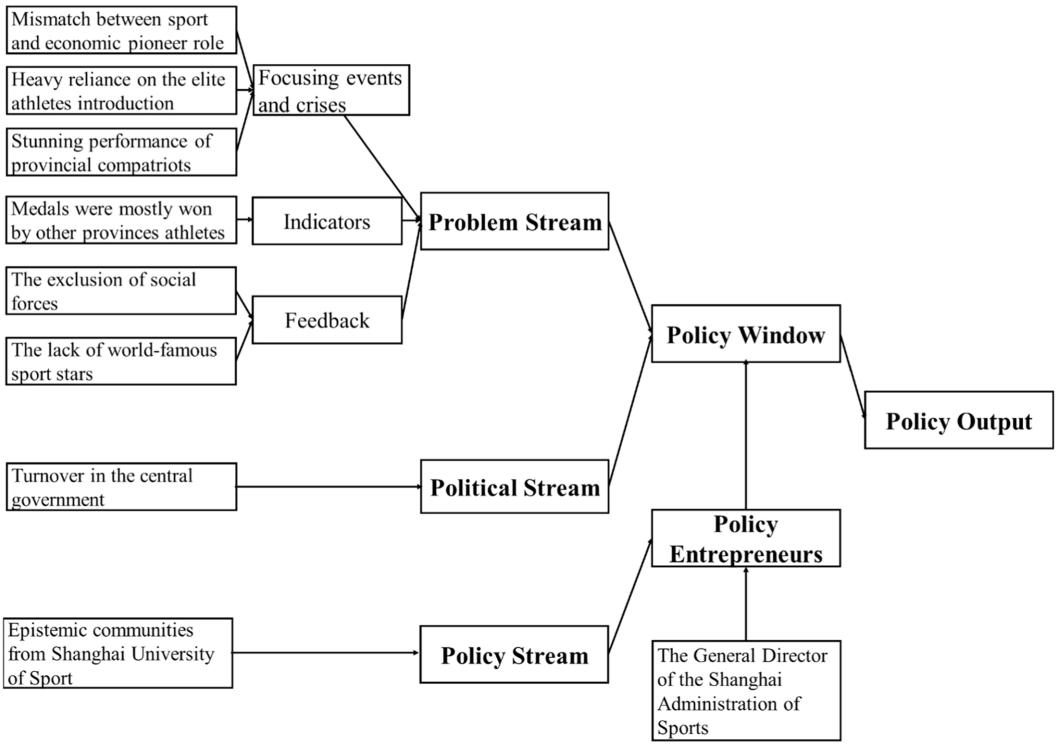

FIGURE 1
Schematic diagram of the theoretical framework.

gold medals obtained by the Shanghai delegation were won by elite athletes from other countries), and feedback on the effectiveness of existing policies (the exclusion of social forces from the Shanghai elite sport landscape and the lack of emphasis on nurturing world-famous sport stars).

Policy stream and policy entrepreneurs

The policy stream can be interpreted as a simplified '*primeval soup*' of ideas (Parsons, 1995). Ideas are advocated by policy communities that are composed of specialists. Policy communities were described by Kingdon (1984, 1995) as performing either individually or together to fulfil shared goals. However, for this research, the notion of an '*epistemic community*' developed by Haas (2009) is more suitable because the set of alternatives to the governmental agenda was initiated by scholars at Shanghai University of Sport, as was confirmed by Interviewee D:

As the only sport-specific university in Shanghai Municipality, Shanghai University of Sport shouldered the responsibility to draft a set of alternatives to the governmental agenda. Several professors specializing in elite sport and elite sport policy were selected for intellectual thinktanks (Interviewee D).

The term '*epistemic community*', or '*intellectual thinktanks*', which refers to a network of professionals with renowned expertise and competence in a specific area (Haas, 2009, 3), is beneficial for understanding the policy stream considered in this research. Of particular importance is that the knowledge-based (epistemic) communities from Shanghai University of Sports can examine cause-and-effect relationships and further propose specific policies.

Policy entrepreneurs are eager to advocate their favoured ideas among policy communities and even wider audiences with the aim of increasing the acceptance of their ideas. Echoing Peng et al.'s (2019) and Wu's (2021) assertions, I noted that policy entrepreneurs from mainland China are always characterized by bureaucratic attributes. In this research, the general director of the Shanghai Administration of Sports is recognized as playing a central role in policy making. Elite sport policy reform is a highly sought-after outcome for the general director of the Shanghai Administration of Sports. Interviewee C clarified the underlying rationale for this role:

Our general director has the greatest personal motivation to play a central role and facilitate policy change in Shanghai elite sport, pushing the sporting performance of the Shanghai delegation at the NGC platform to a higher level. The underlying rationale is that the medals obtained from the NGC, particularly, the gold, have a direct relationship with job promotion. Fully immersing in the policy reform of elite sport is his normal routine (Interviewee D).

Political stream

The political stream involves factors creating an environment beneficial to agenda change (Ackrill and Kay, 2011). Kingdon (1984, 1995) illustrated the political stream as having the following three influencers: the national mood, organized political forces, and the government (legislative and administrative turnover). Within the Chinese context, there is no democratic tool equivalent to the public referendums seen in Western societies to determine whether the national mood towards elite sport development is positive or negative. In a similar vein, the CPC will never permit organized political forces to exert any impact on the governmental agenda (Zheng, 2017; Peng et al., 2019). With regard to the third element of the political stream, the ascension of a new president or new secretary of a state implies potential changes (Travis and Zahariadis, 2002). Turnover in the central government strongly influences the SMG's willingness to initiate policy changes in elite sport, *inter alia*, in the area of professional football (Interviewee C).

The SMG is obliged to make prompt, positive and concrete responses to President Xi's three wishes for Chinese football: participating in the World Cup, hosting the World Cup, and being World Cup champions. Professional football is regarded as an effective tool for facilitating the formation of the talent pool. The SMG is eager to reform the old elite sport system, especially in the area of professional football (Interviewee C).

Discussion

Much of the extant research in the field of sport management and sport policy has focused on elite sport policy at the national level (Piepiora, 2019), which has created a gap in the understanding of the reform process of elite sport policies at the provincial level. In addition, most discussions of the policy reform of Shanghai elite sport are predicated on a single, salient casual event, the persistent underachievement of the Shanghai delegation in the NGC platform or the pursuit of rapid success, which could short-circuit the development of Shanghai elite sport. Clearly, no individual component is sufficient for fully interpreting the policy reform. The contribution of the MSF to this case study was to draw together these elements in the policy window. The MSF is well-suited for studying Shanghai's elite sport policy, which further supports the decontextualization process of the model. First, the problem stream includes concerns that draw the attention of policy-makers (Ackrill and Kay, 2011). For example, the problem stream comprises the following factors: focusing events and crises (the mismatch between Shanghai's sport performance and its role as an economic pioneer, the heavy reliance on the introduction of elite athletes from other provinces, and the stunning performance of provincial compatriots), indicators (a large percentage of the total gold medals obtained by the Shanghai delegation were won by elite athletes from other provinces), and feedback on the effectiveness of existing policies (the exclusion of social forces from the Shanghai elite sport landscape and the lack of emphasis on nurturing world-famous sport stars).

The policy stream is where ideas and proposals are formulated and revised (Ackrill and Kay, 2011). In the present case, this stream is strengthened by knowledge-based (epistemic) communities from the Shanghai University of Sports, which share

a common concern in a single policy area (elite sport) and can examine cause-and-effect relationships and further propose specific policies. The general director of the Shanghai Administration of Sports is recognized as playing a central role in advocating for policy proposals. This finding echoes Ackrill and Kay's (2011) and Bakir and Jarvis's (2017) argument that it is unlikely that a single person can be solely responsible for such a change. However, it is arguable that individuals can play a central role in the policy change process.

The political stream is mainly manifested as governmental influence (legislative and administrative turnover). Turnover in the central government has strongly influenced the SMG's willingness to initiate policy change in elite sport, particularly in the area of professional football. Considered collectively, the problem, policy and political streams have emerged and combined into a single unit with the support of policy entrepreneurs, which significantly increases the possibility of a consensus regarding policy change (reform). With the opening of the policy window, rather than simply being pushed into obscurity, the issue of elite sport policy change has reached the top of the decision agenda in Shanghai and received serious attention from policymakers. Kingdon (1984, 1995) clarified the difference between decision agendas and governmental agendas. When a policy is on the decision agenda, it has a more active status than when on the governmental agenda.

Ultimately, this research both makes academic contributions and has practical utility. In relation to academic contributions, although the MSF, which was introduced by Kingdon in the United States, is being increasingly adapted to the study of Chinese policy-making, this research has revealed a theoretical underdevelopment in some of its central components. Theoretical development was first achieved by enriching the content of the '*focusing events and crises*' factor by adding the overshadowing performance of provincial compatriots. Guangdong, as a provincial compatriot of Shanghai, has exerted tremendous effort and made notable achievements in professional football, which acts as a powerful stimulant for and has facilitated the policy change process for elite sport in Shanghai. Second, in the application of the MSF to Shanghai studies, it is argued that compared with the broader concept of '*policy community*', the term '*epistemic community*' is much more appropriate in this study. This adaptation is relevant to the present case study. However, this research's support for the '*epistemic community*' comes with the caveat that our case centres on knowledge-based communities from the Shanghai University of Sports. The final theoretical contribution offered refers to the term 'policy entrepreneur'; Ackrill and Kay's (2011) unambiguous distinction between individuals who are policy entrepreneurs and the process of policy entrepreneurship may have some implications for this research. The general director of the Shanghai Administration of Sports can act as a policy entrepreneur in selling a policy proposal, but he or she may not be aligned with Kingdon's (1995) construct of a policy entrepreneur due to his or her institutional role. In the Chinese context, participants who hold formal positions always play a crucial role in the decision-making process (Peng et al., 2019, 6). Hence, in our case, policy entrepreneurship is understood as a temporary characteristic that is context- and situation-specific and is considered a dynamic entity with the potential for continual changes over time. In practical terms, from the standpoint of policy makers in Shanghai, this research provides a valuable opportunity to review the corresponding policy trajectory to improve the effectiveness and efficacy of existing policies.

It is worth noting that this research has several limitations, but it also offers directions for future research. First, this research employed qualitative techniques and focused on 'thick description' (Tracy, 2010) and the uniqueness of the *broader distal environment* (Chelladurai, 2014). I recognize that this method is potentially limited in its ability to generalize our findings (Gratton and Jones, 2010) and offer an '*all-powerful formula*' (Zheng et al., 2018b), '*one-size-fits-all*' solution (Cloete and De Coning, 2016) or '*silver bullet*' (Wu, 2021) that is useful to all other nations or regions. Nevertheless, audiences both within and outside academia are encouraged to evaluate the transferability of the results by further analysing the intricacies of each context.

Second, in line with the argument made by Barzelay and Gallego (2006), this research uses problem, policy and political streams as descriptive heuristics to aid the organization of a historical policy narrative. Further studies are encouraged to probe into the nature and duration of policy spillover within multiple institutionally connected policy fields. Unfortunately, Kingdon (2003, 190) mentioned only the exogenous spillover between institutionally unrelated policy areas and thus seriously neglected the endogenous spillover supplemented and elaborated by Ackrill and Kay (2011) in their analysis of sugar reform in EU policy-making. Interestingly, the endogenous spillover between multiple institutionally connected policy areas can manifest in policy windows that are open for longer periods of time. This argument, to some extent, explains the relatively delayed sport policy reform in contrast to the prompt action in economic areas within the Chinese context.

Third, the PRC, which is the world's second-largest country by land area, covers approximately 9.6 million square kilometres with a population of over 1.35 billion people and is structured into 22 provinces, 5 autonomous regions (Guangxi Zhuang, Inner Mongolia, Ningxia Hui, Tibet and Xinjiang Uygur), 4 directly controlled municipalities (Beijing, Chongqing, Shanghai and Tianjin) and 2 special administrative regions (Hong Kong and Macau). The majority of these jurisdictions each have populations of approximately 10 million people. Some of these jurisdictions have fewer than 9 million inhabitants (Hainan, Ningxia, Qinghai and Tibet), whereas other provinces (Anhui, Guangxi, Shandong, Yunnan and Zhejiang) have over 45 million citizens (National Bureau of Statistics, 2010). Provincial-level sport research holds intriguing academic potential in examining regional diversity, administrative complexity and the significant gaps in the sport policy and management literature. This finding highlights the need for more in-depth research on provincial-level sport development.

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

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

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

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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.

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How can social needs impact on meaningful sports consumption?

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The main goal of this study is to explore the drivers of meaningful sport consumption and its influence mechanism. In sports consumption, consumers not only seek hedonic value but also pursue to experience greater purpose and meaning in life, which is regarded as meaningful sports consumption. This study extends existing sports management literature by examining how social needs impact meaningful sports behavior with team affiliation, self-improvement, and self-esteem as mediators. Based on the questionnaire data collected from China, the empirical analysis results show that social needs have a significant positive impact on meaningful sports consumption behavior through the mediating effect of team affiliation and self-esteem motivation. However, self-improvement motivation does not have a mediating effect on the relationship between social needs and meaningful sports consumption. This study enriches the research content of sports consumption, adds research object of social needs, and expands the research scope of meaningful consumption by introducing meaningful sports consumption into the above domain.

KEYWORDS

meaningful sports consumption, social needs, team affiliation, self-improvement, self-esteem

Introduction

Nowadays, people participate in sport activities greatly in both developed and emerging countries, forming a huge growing sports consumption market (Andreff and Andreff, 2009). Sports consumption means the expenditure of consumer spend on sports, which includes the consumption in all kind of sports products or services such as sportswear and equipment, watching sports games, expense in sports media, expense in sport participation, and etc. (Lera-Lopez and Rapun-Garate, 2007). Because the sports industry is becoming a growing economic sector, a large number of companies provide a wide range of sport products and service to this market (Andreff and Andreff, 2009). As an important social and economic phenomenon, sports consumption attract the attention of a lot of research (Karg and McDonald, 2011; Thibaut et al., 2014). These research involve determining factors of sports consumption (Thibaut et al., 2014), motivation of sports consumption (Byon et al., 2020), influence of sports consumption (Oh et al., 2022), and so on.

Previous studies on sports consumption focus on hedonic sports consumption, which means consumers pursue hedonic benefits from the consumption (Hall, 2015). However, besides pure pleasure, consumers also experience deeper meaning and greater purpose in life, which is conceptualized as meaningful sports consumption by researchers (Jang et al., 2020). For example, audience appreciate athlete's moral beauty of helping competitors or others in competition, which is regarded as meaningful behavior, for it will be more prosocial in the future (Jang et al., 2019). Therefore, consumers want to find deeper meanings from human greatness and moral excellence as well as simply positive affects in their lives in sports consumption (Wirth et al., 2012).

Although meaningful sports consumption has been proposed to represent a unique behavior of sports consumption to distinguish traditional hedonic sports consumption, the studies on the area are very rare. Jang et al. (2019) suggested that meaningful messages can improve sports consumers' supportive behavior of athletes' foundation (Jang et al., 2019). In addition, Jang et al. (2020) discussed how will consumer response to meaningful sports consumption psychologically and behaviorally in different meaningful sports consumption context. However, what trigger consumers' meaningful sports consumption and the mediating mechanism are not explored. Therefore the main goal of this study is to explore the drivers of meaningful sport consumption and its influence mechanism.

Individuals' need is the drive of their consumption behavior. Compared with hedonic consumption, meaningful consumption usually arise from social needs (Syrjälä et al., 2015). Meanwhile, individuals' need is usually the antecedent of their motivation of behavior, including consumption behavior (Taljaard and Sonnenberg, 2019). For individuals, team affiliation, self-improvement, and self-esteem are motivations arisen from social needs but not from hedonic need (Jang et al., 2020). Therefore, this study constructs a theoretical model based on the theory of hierarchy of needs and sports consumption motivation in a meaningful sports consumption context, with social needs as the antecedent variable and team affiliation, self-improvement, and self-esteem consumption motivation as the mediator. The sports consumption in this study refers to the universal consumption behavior in sports, including watching sports game, purchase of sportswear, participation of sports. The study explores forming mechanism of meaningful sports consumption, deepening the research on meaningful sports consumption. At the same time, it provides suggestions for sports companies to enhance the values of their products or services by endowing more humanistic significance to products or service.

Literature review

Meaningful sports consumption

Meaningful sports consumption can be divided into two types based on different ways of self-construal. One is from a self-oriented perspective that highlights the extraordinary skills of athletes that make sports consumption meaningful, and the other is from an other-oriented viewpoint that emphasizes the exceptional moral qualities of athletes that make sports consumption meaningful (Jang et al., 2021). In a study on sports media consumption, it is found that audience have unique emotional dispositions toward athletes or teams. Audience's positive emotions are enhanced when teams or athletes with positive tendencies win or when teams or athletes with negative spirits lose (Chiu and Won, 2022). However, in actual sports events, inconsistencies between game results and spectators' expectation can lead to negative spectator emotions. Therefore, to attract audience to watch the game, sports media may bring them alternative satisfaction by evoking a meaningful feeling (Hall, 2015). For example, the sense of connection established between the audience and the team, the player, or other fans can awaken the individual's moral perception of team spirit and team loyalty (Winegard and Deaner, 2010), thus increasing the game's attractiveness. Sports media consumption can stimulate meaningful social cognitive experiences that foster human insight, significant perception, and socially connected emotional well-being in a more complex and sustainable way (Oliver and Bartsch, 2010; Oliver and Hartmann, 2010; Wirth et al., 2012). Rogers (2018) likewise points out that sports media can provide both pleasurable enjoyment and meaningful experiences for viewers, suggesting that sports consumption can be a more profound, significant consumption experience (Rogers, 2018). Sports consumers also view sports media entertainment that showcases athletes' exceptional skills (Biscaia et al., 2012), their spirit in overcoming obstacles to reach their goals (Onu et al., 2016), and inspirational stories (Oliver et al., 2018) as meaningful consumer experiences.

The early sports management literature focused on how participation in various sports consumption provides hedonic benefits to sports consumers and determines their subsequent consumption behavior (Biscaia et al., 2012). As a new conceptualization of consumption, the most intuitive basis for distinguishing between hedonic and meaningful sports consumption is the triggering of self-transcendent emotions, namely the "higher" intrinsic needs identified in self-determination theory. Specifically, participation in meaningful sports consumption leads to a greater sense of upliftment than participation in hedonic sports consumption, as it provides opportunities for personal growth and self-development and is a critical component of self-transcendence (Jang et al., 2020).

While previous research has found that positive affect is a significant predictor of entertainment (David et al., 2008), a finding that is consistent with popular perception, Rogers (2018) also found a significant positive correlation between negative affect and entertainment. Oliver discusses why the public goes for tear-jerking, sad films (Oliver, 1993). The entertainment experience in such movies may not be hedonistic but rather provide viewers with a sense of meaningful connection, insight into the human condition, and the opportunity to explore complex moral issues (Tamborini, 2011). The motivation for watching sad

movies is no longer the entertainment motivation of seeking a single dimension of pleasure but the happiness motivation of pursuing an additional size of meaning in life (Oliver, 2009). Oliver further confirmed in his study that happiness motivation is an antecedent variable that influences meaningful consumption behaviors such as watching a tragedy or witnessing moral beauty in the audience (Oliver and Raney, 2011).

By introducing the sense of self-improvement variable in study, Jang et al. (2019) confirmed that people trigger a sense of individual improvement by watching meaningful videos, enhancing their intention further to share these videos as a form of pro-social behavior (Jang et al., 2019). Bartsch et al. (2018) explored how empathy induced by the image of Paralympic athletes can indirectly influence public awareness and destigmatize through the negative emotion of pity to lead to a general shift in pro-social attitudes toward people with disabilities among sports viewers.

In summary, meaningful sports consumption is not purely hedonic or associated only with positive emotional experiences. It also provides some emotional experiences that can be interpreted as unfavorable, resulting in feelings of meaningfulness. In other words, meaningful sports consumption seeks not only to experience positive emotions but also to be driven by happiness and motivation to pursue deeper life goals and meaning (Rieger and Hofer, 2017).

Theory of sports consumption motivation

Motivation is defined as "the behavior of people that creates an internal drive to move toward a desired goal" (Armstrong et al., 2014). And consumer motivation is the consumer's perceived demand function through the consumer decision process to become the driving factor, catalyzing the formation of willingness to buy or achieve purchase behavior (Iso-Ahola et al., 1999). Based on the definitions of motivation and consumer motivation, scholars have conceptualized the theory of sports consumption motivation from sociological and psychological perspectives.

There are different ways to classify the dimensions of sports consumption motivation in current studies. Wann was the first to develop the Sports Consumption Motivation Measure Scale (SFMC) using the sociology of sport theory, which classified sports consumption motivation into eight dimensions, including mild stress, self-esteem, escape, recreation, economy, esthetics, group belonging, family needs and so on (Wann, 1995). Milne and McDonald further proposed the Motivations of Sport Consumer (MSC) theory, which includes 12 motivational factors, including self-esteem, self-actualization, social interaction, and a sense of affiliation (Milne and McDonald, 1999). Funk et al. (2009) considered the shortcomings of existing research results in terms of complex dimensions and unfavorable application practices and optimized sports consumption motivation into five dimensions, namely socialization, entertainment, excitement, self-esteem, and distinction, developing the SPEED scale accordingly.

Different consumption motives will cause different consumption behaviors. Therefore, different dimensions of sports consumption motives will develop different nature of sports consumption behaviors accordingly. For example, in conspicuous consumption research, it has been demonstrated that self-esteem motivation can significantly influence apparent consumption behavior (Thoumrungroje, 2014). Chen explored the relationship between the motivation of professional soccer club fans to watch matches and their purchasing behavior in terms of the dimensions of star-following motivation, hobbies, and motivation to gain a sense of regional affiliation (Chen et al., 2014). Chu et al. (2019) examined the impacts of team affiliation, self-improvement motivation, and consumer engagement on Chinese travelers' electronic word-of-mouth.

In summary, team affiliation, self-improvement, and self-esteem motivations are essential motivations of consumers, which essentially reflect consumers' pursuit of meaningful values beyond the intrinsic use and enjoyment values of material goods. Therefore, this paper selects team affiliation, self-improvement, and self-esteem motivations as the focus of the study in the context of meaningful sports consumption to explore how these three types of sports consumption motivations play a mediating role in the relationship between social needs and significant sports consumption.

Social needs

The need is a subjective consciousness that arises when the organism lacks a particular substance and is the internal reaction of the organism to objective things. Unlike the single natural biological needs of animals, human needs also include social needs (Gong and Zhao, 2013). Social needs is a particular need acquired by individuals through various experiences during the growth process, which is a kind of advanced human need that includes love, affection, affiliation, and acceptance (Li et al., 2021). As a social being, an individual's natural physical needs have become socialized into personal needs in the process of socialization. At the same time, some social needs beyond the natural ones are generated (Wang, 2003; Rodrigues et al., 2018). Man is a social being and has a deep need to share, help, and feel part of a group (Fromm, 1955). According to Maslow's hierarchy of needs theory, "physiological needs" and "security needs" can be classified as natural human needs. In contrast, "social needs, "respect needs," and "self-actualization needs" are classified as social needs (Yu, 1992). As to people in real life, when a certain kind of need is satisfied, they will further pursue a need at a higher level. The pursuit of higher level needs, the meaning of life, and a better life will become the internal motivation that drives their behavior (Maslow and Xu, 2007).

Social needs have been studied in a variety of fields. Steverink and Lindenberg (2006) investigated how the satisfaction of three human social needs, including affect, behavioral validation and social status, was associated with age, physical loss, and subjective well-being (Steverink and Lindenberg, 2006). It concluded that behavioral validation

needs were more difficult to satisfy at higher levels of physical loss. However, none of the three social conditions became less important with the growth of age. Suki (2013) used multiple regression analysis to verify that the need for sociability significantly influenced students' reliance on smartphones. Yu (1992) discussed the decisive role of social conditions on the development of library business. From the perspective of resource providers, Kong and Zhao (2018) verified that social demand significantly influenced the willingness and behavior of resource providers to participate in sharing economy platforms. Cao et al. (2013) demonstrated that two kinks of social needs, namely emotional belonging and social presence, would jointly positively impact satisfaction with social networking services and intention to continue participation. For social needs is an important drive of consumers' behavior, particularly for the pursuit of values or meaning of life, this paper sets social needs as an antecedent variable to explore whether social needs positively influences meaningful sports consumption behavior.

Model

The study introduced social needs as the independent variable, and use the motivation of team affiliation, self-improvement, and self-esteem in sports consumption as mediating variables. Meaningful sports consumption is the dependent variable in the study to explore the mechanisms of how social needs influence sports consumption behavior. Sports consumption motivation is the direct cause of people's sports consumption behavior. Different sports consumption is driven by different sports consumption motivation. Yet, needs are the subjective desire state of consumers due to the lack of certain things (Chen et al., 2010). The satisfaction of lower-level needs reflects more hedonic considerations. In contrast, the pleasure of higher-level needs (such as social needs) reflects more concern for the happiness and the meaning of life (Oliver and Raney, 2011). Consumer groups with social needs often have a strong sense of family and social subordination, so they regard themselves and the country and society as an inseparable whole and pursue the emotional experience of affiliation to a team in the process of sports consumption (Zhang, 2002). Self-improvement motivation is significantly associated with individual pro-social behavior (Seo and Scammon, 2014), which helps individuals to establish a good impression in social interactions, gain positive recognition from others (Chu et al., 2019) and promote consumer engagement. Self-esteem is the motivation of individuals and groups to achieve higher spiritual and material needs (Funk et al., 2016). The strength of self-esteem motivation significantly affects consumers' decisions and behaviors (Grubb and Grathwohl, 1967). Accordingly, this paper constructs a conceptual model in which social needs influence the formation of meaningful sports consumption behaviors, which is mediated by team affiliation, self-improvement, and self-esteem.

Hypothesis

The impact of social needs on meaningful sports consumption

The intrinsic need is the primary driver of all consumer behavior, thus we can predict consumer behavior with their needs (Yin, 2007). As to fitness consumption, Shi (2021) classify types of demand orientations into hedonic, physical, and social needs. Social needs reflect individuals' higher-level needs, which will give rise to higher-level value demands, significantly influencing consumers' fitness consumption behavior (Shi, 2021). In a consumer-led economy, sports products is evolved to meet the needs of consumers (Zhang, 2005). Wang and Li (2021) pointed out that the need for social recognition is a critical factor in the consumption of green products, which not only have functional ecological benefits (Sadovnikova and Pujari, 2017), but also trigger social and moral values in the consumption process (Muralidharan and Xue, 2016). Higher levels of social needs influence consumers' generation of meaningful sports consumption behaviors. If consumers' social needs are higher, then consumers will engage in relatively higher levels of significant sports consumption behaviors. Accordingly, the following hypotheses are proposed in this study (Figure 1).

> *H1:* Social needs significantly and positively influences meaningful sports consumption behavior.

The impact of social needs on motivation of team affiliation

People's intrinsic need for sports drives sports consumption motivation, that is the need for sports consumption is the basis for the forming of sports consumption motivation (Liu, 2000). Individuals' sports consumption needs are different, making their consumption motives and behaviors different. Among sports consumption, although physical fitness is the most basic kind of sports needs that most people pursue, social needs, which focus on seeking collective identity and realizing self-worth, is also an considerable pursuit of sports consumers. This feeling of affiliation to other individuals or social groups is an instinctive human psychological need (Baumeister and Leary, 1995). Zhang (2002) pointed out that viewers who pursued collective identity-seeking will show a solid motivation to team affiliation to sports teams, which represented a certain group, region, ethnicity, or country. When major competitions involving national interests and prestige are concerned, they are more likely to give rise to their sense of home and national consciousness (Zhang, 2002; Kolesovs, 2021). Accordingly, the social needs is supposed to give rise to the consumption motive of team affiliation. Therefore, this paper proposes the following hypothesis.

> *H2:* Social needs significantly and positively influences consumers' motivation of team affiliation.

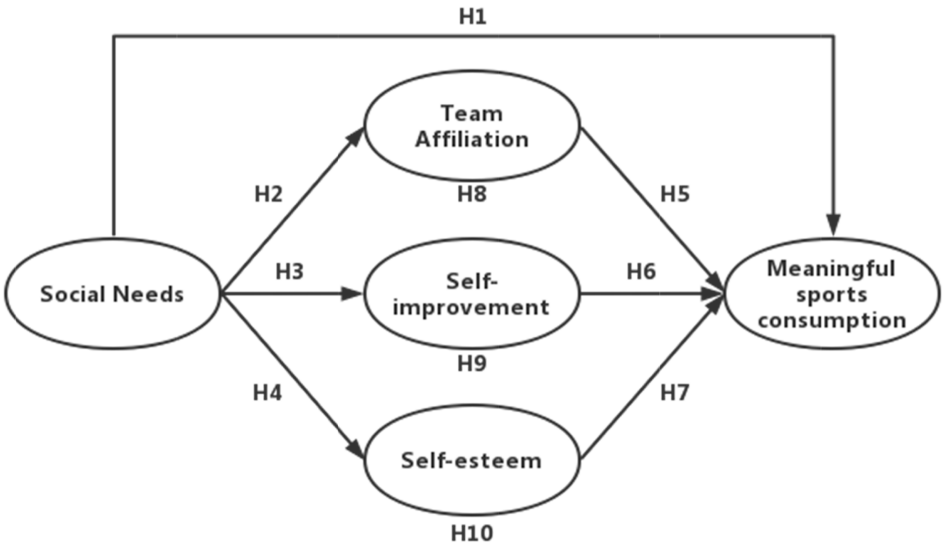

FIGURE 1
Framework of model.

The impact of social needs on motivation of self-improvement

Self-improvement motivation refers to the desire of individuals to enhance their self-concept and acquire a good self-image (De Angelis et al., 2012). In meaningful sports consumption situations, self-improvement-oriented individuals are more inclined to receive feedback that can enhance the spiritual aspects of their personality, morality, and social values in the future. Seo and Scammon (2014) demonstrated a significant positive correlation between interdependence among social groups and self-improvement motivation in the pro-social behavior of helping people. In interpersonal interactions, the satisfaction of interdependence reflects the pursuit of people's need for sociality. Leary (2007) argued that self-improvement motivation is rooted partly in people's concern for social approval and acceptance that can protect people's pursuit of subjective social well-being (Leary, 2007). Therefore, it can be argued that the most crucial function of self-improvement motivation is to satisfy social needs such as social interaction and interpersonal communication. Accordingly, this paper proposes the following research hypothesis.

> *H3:* Social needs significantly and positively influences consumers' motivation of self-improvement.

The impact of social needs on the motivation of self-esteem

Currently, the theories related to self-esteem include dominance theory, social scale theory, and fear control theory, all of which jointly point out that self-esteem is an individual's self-evaluation of their social attributes, that is, self-esteem refers to an individual's subjective evaluation of their self-value as a human being (Orth and Robins, 2014). Funk et al. (2016) found that self-esteem, respect, and ambition are the key motives associated with the satisfaction of self-achievement needs in the consumption process. Once individuals wish to achieve more social recognition than others, they will not only have a stronger sense of self-consciousness but will also inspire higher levels of self-esteem. According to Maslow's hierarchy of needs theory, the highest level of social needs is the need for self-actualization. In addition, in the organism theory, it is stated that one of the leading human needs tendencies to reach self-actualization is the need for self-improvement (Ford, 1991). Meanwhile, Baumeister (1997) pointed out in his study that the need for self-improvement is an innate drive for individuals to improve their self-esteem (Baumeister, 1997). In summary, social needs influences self-improvement motivation through its self-actualization needs dimension, which further influences individuals' self-esteem motivation through self-improvement motivation. Accordingly, the following hypothesis is proposed in this paper.

> *H4:* The consumers' social needs significantly and positively influences their self-esteem motivation.

The impact of team affiliation motivation on meaningful sports consumption behavior

Ko et al. (2017) pointed out that sports consumers actively seek opportunities to satisfy their motivation to affiliation to a team by participating in sports clubs or watching sports teams play and create a sense of affiliation by engaging in various sports experiences. Related studies took team affiliation motivation as one of the essential dimensions influencing fans' motivation to watch games and concluded that spectators with strong team affiliation motivation generally have strong ethnic

sentiments (Mutz and Gerke, 2018). When it comes to their own ethnic team's games, they are also the most emotionally invested in the fun. This kind of emotion tend to dominate the atmosphere and emotional reactions in the games. Funk et al. (2001) found that team-attached consumers take pride in their community and watch more community-related games on television (Funk et al., 2001), while the international nature of World Cup events replaces this community pride with a corresponding sense of national pride. The consumption phenomenon of watching games supporting one's team out of ethnicity or regional affiliation can be categorized as meaningful sports consumption behavior. With this in mind, the following hypotheses are proposed in this paper.

> *H5:* consumers' team affiliation motivation significantly and positively influences meaningful sports consumption behavior.

The impact of self-improvement motivation on meaningful sports consumption behavior

Material wealth is essential to the concept of self and can even be seen as an extension of the self, thus images related to the self (e.g., self-improvement, self-esteem, self-consistency) influence consumers' purchases of material goods (Lu, 2019). In the context of research on sports consumption, Jang et al. (2020) found that sports consumers are more likely to support athlete-run charitable foundations through a sense of self-improvement when viewers watch promotional videos that show the meaningful behavior of athletes. At the same time, sports events or promotional videos that showcase athletes' outstanding ethics or superior skills can lead to a greater sense of uplift among sports consumers, which significantly determines the consequences of their behavior (Jang et al., 2019). Emotional triggers for self-transcendence (e.g., elevation, admiration, and awe) have also emerged as critical factors in helping scholars conceptualize meaningful consumption (Oliver et al., 2018). Accordingly, the following hypotheses were formulated in this study.

> *H6:* Self-improvement motivation significantly and positively influences meaningful sports consumption behavior.

The impact of self-esteem motivation on meaningful sports consumption behavior

Self-esteem motivation can impact how people behave and has a motivating effect on some of their behaviors, which is one of the main drivers that motivate consumer decisions and behaviors (Grubb and Grathwohl, 1967; Philp et al., 2018). It is indicated that from the perspective of status consumption self-esteem motivation can significantly and positively promote consumers to consume certain social status goods that can represent their attributes or status expectations (Liu and Li, 2022). Products related to status have not only simple use value, but also have symbolic added value (McDonald et al., 2002). Meanwhile, studies on how self-esteem motivation influence consumer behavior have also focused on the area of conspicuous consumption (Khan and Dhar, 2006; Widjajanta et al., 2018), in which a significant positive relationship between self-esteem motivation and conspicuous consumption has been confirmed. In essence, conspicuous consumption is a kind of consumer behavior in which people seek a higher level of spiritual satisfaction and social identity after satisfying their basic material needs. The process is also given the symbolic meaning of displaying oneself, which has the same connotation as meaningful consumption. The nature of self-esteem motivation influencing consumption behavior also applies to the meaningful sports consumption context, where individuals with higher levels of self-esteem motivation tend to consume the significant value behind sports. Accordingly, this paper proposes the following hypothesis.

> *H7:* Self-esteem motivation significantly and positively influences meaningful sports consumption behavior.

The mediating role of team affiliation

Consumer behavior is determined by the diverse needs of consumers. Namely different needs will induce different consumption motives. And then, based on the nature of the dominant motive among the many consumption motives, corresponding consumption behavior is induced. Wann et al. (2001) suggested that sports event spectators can motivate team affiliation by sharing social identities with other fans or social groups (Wann et al., 2001). Shared social identities reflect the social interaction dimension of the public's social needs, which generate the motivation to affiliation to a team. Feeling connected and socially interacting with each other is a social experience of watching sporting events. When social needs are met through belonging experiences, a sense of well-being and satisfaction is generated accordingly (La Guardia et al., 2000). Chu et al. (2019) explored the relationship between affiliation motivation and consumer engagement using Chinese consumers' WeChat friend circle as a research object. The study showed that Chinese consumers' higher sense of affiliation or attachment to their friend circle positively influences their WeChat consumption engagement. In summary, social needs motivate consumers' motivation to affiliation to a team, and this motivation further affects consumption behavior. Accordingly, this paper proposes the following research hypothesis.

> *H8:* Team affiliation motivation plays a mediating role in the relationship between social needs and meaningful sport consumption behavior.

The mediating role of self-improvement

Individuals need to meet the need from group or society and meet the personalized need, such as the realization of self-value, which determines the behavior of personal sports consumption tendency and consumption motivation. And self-improvement

motivation is an important mechanism that mediates the influence of the external social environment on the internal self, which can help people innovate their self-behavior, form a long-lasting and stable self-system, and become a significant motivation to mark the self (Kurman, 2006). It has also been shown that individuals will continuously improve themselves to achieve the behavioral standards assigned by specific social roles to become a better self in a given society, which also suggests that the satisfaction of social needs within the broader framework of the social environment will further enhance individuals' motivation for self-improvement. In the consumption context, it was found that when individuals are in a crowded social environment, they are more likely to be motivated by self-improvement and thus more inclined to engage in self-improvement consumption (Ding and Zhong, 2020). Consumption behaviors that enable individuals to perform a task better or enhance certain aspects of themselves are categorized as self-improvement consumption (Allard and White, 2015). In summary, self-improvement motivation is generated by the social needs of individuals. Under the improvement of this motivation, people are more likely to pursue those consumptions that can lead to self-improvement. Accordingly, this paper proposes the following research hypothesis.

> *H9:* Self-improvement motivation has a mediating role in relationship between social needs and meaningful sport consumption behavior.

The mediating role of self-esteem

Self-esteem motivation reflects the extent to which a person believes that participation in sporting events provides an opportunity for alternative achievement (Funk et al., 2009). This opportunity for achievement and challenge gives individuals with individual and collective self-esteem an incentive to pursue new sports consumption experiences. Research has shown that when faced with the experience of success or failure of the team they support, such incidents are more likely to positively or negatively affect the satisfaction of personal well-being needs when individuals have higher levels of self-esteem (Kim et al., 2017). The satisfaction of happiness needs is one of the prerequisites of social needs to realize our pursuit of a good life (Schippers and Ziegler, 2019). It was noted that as consumers build and maintain self-esteem through association with sports teams, they are more likely to attend future games and purchase merchandize (Trail et al., 2005). Even in unsuccessful seasons, the adverse effects that affect continued participation are temporary for fans with high self-esteem (Bizman and Yinon, 2002). The nature of this consumption phenomenon is consistent with the connotations of meaningful sports consumption that we have explored. The strength of the social needs positively influences the level of self-esteem motivation of the individual. Meanwhile, the higher the level of self-esteem motivation, the stronger the connection between the individual and their favorite sports team or regional representative team, which in turn influences consumers' subsequent consumption decisions and consumption behavior. Accordingly, this study proposes the following hypothesis.

> *H10:* Self-esteem has a mediating role in the relationship between social needs and sport consumption behavior.

Methodology

Sample selection

In this paper, Chinese consumers who have participated in sports consumption were used as the respondents of a questionnaire survey to explore the influencing factors that affect consumers' behavior of engaging in meaningful sports consumption. The subject of sports consumption refers to the ordinary individuals who buy sport product and service as consumers. The survey process was divided into a pre-survey and a formal survey. The questionnaire was reworked to address the pre-survey's vague expressions and linguistic ambiguities. In the survey process, a combination of online questionnaire survey and offline distribution of paper questionnaire survey was used, and 355 questionnaires were distributed. 298 valid questionnaires were collected after eliminating invalid questionnaires such as too fast response time and regular distribution of answers. The descriptive statistics of sample is shown in the following Table 1.

TABLE 1 Descriptive statistics of samples.

Classification indicator	Categories	Frequency	Percentage (%)
Gender	Male	135	45.3
	Female	163	54.7
Ages	<18	96	32.2
	18–25	172	57.7
	26–35	21	7.0
	36–45	2	0.7
	>45	7	2.3
Education level	High school and below	58	19.5
	Junior college	71	23.8
	Undergraduate	96	32.2
	Master and above	73	24.5
Monthly income	<3,000	211	70.8
	3,000–5,000	41	13.8
	5,000–8,000	29	9.7
	>8,000	17	5.7
Monthly sports consumption expenditure	<200	181	60.7
	200–500	66	22.1
	500–1,000	33	11.1
	>1,000	18	6.0

Measurement

The measurement scales for variables in this study is well established in existing studies. We use them as the measurement in this study with some items adjusted according to the actual situation of the study context. The process of scale development is as follow. Scales of variables in this study were collected from existing literature. Then the question items were adjusted according to the context of the study through group discussions. Finally, the scales of variables in this study are determined (see Table 2). This study includes the scales of social needs, team affiliation, self-improvement, self-esteem and meaningful sports consumption. The scale questions were based on the Likert 7-point scale, with 1 indicating complete disagreement and seven indicating entire agreement. As to the measurement questions, social needs refers to the study of Shen and Hu (2009). Team affiliation motives refer to the study by Zhang et al. (2016). Self-improvement motivation refers to the study of Jang et al. (2020). Self-esteem motivation refers to the study of McDonald et al. (2002). Meaningful sports consumption refers to the study of Jang et al. (2021). For the details of variables measurement, it can be seen in Table 2.

Results

Measurement model test

Confirmatory factor analysis is used to test the reliability of the data, which shows that the measurement models fit well: χ^2/df = 1.545, RMR = 0.137, GFI = 0.924, AGFI = 0.878, PGFI = 0.577, TLI = 0.897, CFI = 0.926, and RMSEA = 0.043. As shown in Tables 2, 3, combined reliability of all structural variables is above the recommended level of 0.70 and the average variance extracted (AVE) is also above the recommended level of 0.50, which indicates that this study has good reliability for the measurement of the structural variables in the study. The standardized factor loadings for all structural variables are higher than 0.7 and significant at the $\alpha = 0.01$, indicating that the scale has high convergent validity. In addition, the square root of all AVEs is greater than their row and column correlation coefficients, which indicates that the scale has high discriminant validity.

Structural model test

The model fit goodness-of-fit statistics are χ^2/df = 1.841, RMR = 0.096, GFI = 0.949, AGFI = 0.910, PGFI = 0.538, TLI = 0.958, CFI = 0.973, and RMSEA = 0.053. These statistical values indicate that the structural model fits well. Figure 2 shows the results of the path analysis of the structural equation model.

The tests of the structural model included the estimated path coefficients and the tests of the model's explanatory power. The model's standardized path coefficients are shown in Figure 2. The social needs had a significant impact on both consumption motivation and meaningful sports consumption behavior, with meaningful sports consumption ($\gamma = 0.328$, $p < 0.001$), team affiliation ($\gamma = 0.28$, $p < 0.001$), self-improvement ($\gamma = 0.377$, $p < 0.001$), and self-esteem ($\gamma = 0.534$, $p < 0.001$). Consumption motivation had a partial effect on meaningful sports consumption, with team affiliation ($\gamma = 0.316$, $p < 0.001$), self-esteem ($\gamma = 0.268$, $p < 0.01$) having a significant impact on meaningful sports consumption, but self-improvement ($\gamma = -0.183$, $p > 0.05$) doing not have a significant impact. Therefore, research hypotheses H1–H7 are supported except for H6. There is no significant influence relationship between self-improvement motivation and

TABLE 2 Questionnaire items.

Latent variable	Item	Load	SD	AVE	CR	Cronbach's α
Team affiliation	Sense of nationality and patriotic feelings	0.702	0.084	0.544	0.781	0.749
	Feel proud	0.777				
	Interest in relevant information	0.731				
Self-esteem	Self-esteem	0.900	0.114	0.813	0.928	0.911
	Self-confidence	0.949				
	Pride	0.854				
Self-improvement	Admire excellent skills	0.737	0.071	0.742	0.896	0.767
	Moral improvement	0.838				
	Enhance perseverance	0.702				
Meaningful sports consumption	Support domestic sports products	0.743	0.068	0.579	0.804	0.772
	Watch my country's (local) team play	0.834				
	Buy sports tickets to support the development of domestic (local) sports	0.701				
Social needs	Healthy image	0.863	0.147	0.742	0.896	0.859
	Image of love for life	0.898				
	Social status and positive image	0.822				

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TABLE 3 Correlation coefficient of latent variables.

	Social needs	Meaningful sports consumption	Self-improvement	Self-esteem	Team affiliation
Social needs	0.861				
Meaningful sports consumption	0.542	0.76			
Self-improvement	0.405	0.408	0.861		
Self-esteem	0.609	0.461	0.566	0.901	
Team affiliation	0.327	0.556	0.588	0.618	0.736

The diagonal data of the matrix represent the square root of the AVE values and the lower half of the matrix represents the correlation coefficient.

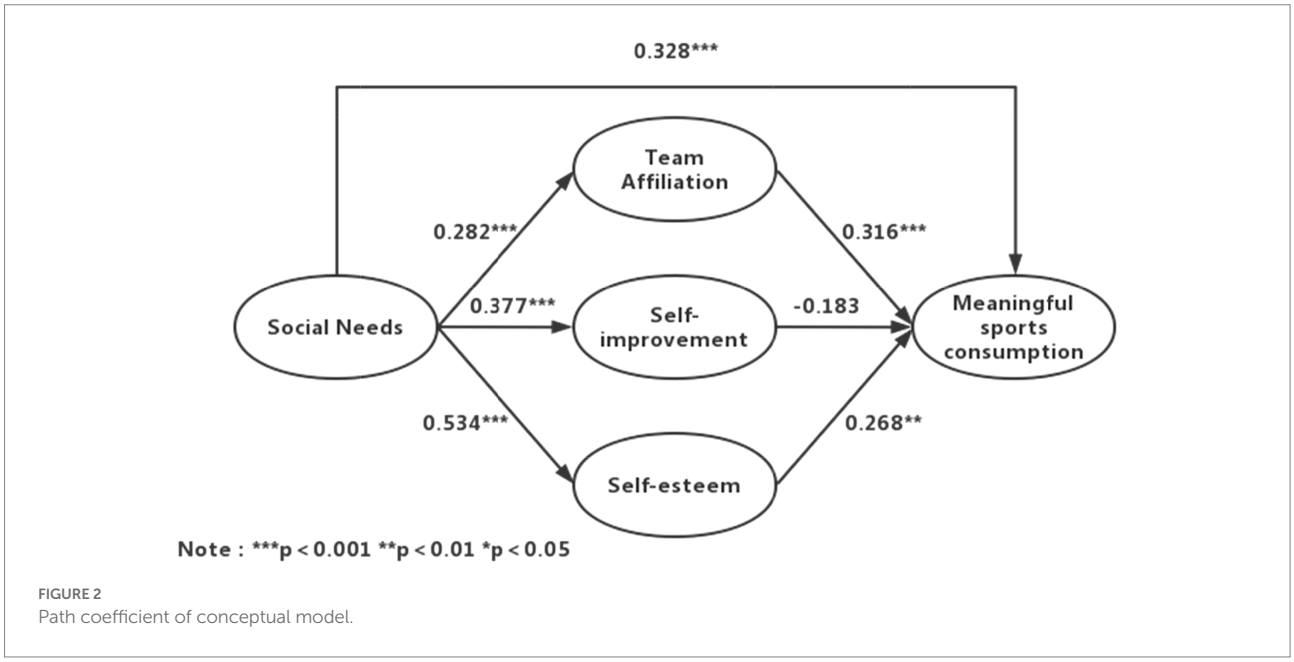

FIGURE 2
Path coefficient of conceptual model.

meaningful sport consumption behavior, so there is no mediating effect of self-improvement motivation in the mechanism of the role of social needs to influence meaningful sport consumption, resulting in H9 failed to be supported.

Mediating effect test

To verify the mediating effect of team affiliation and self-esteem, this paper uses the Boot-strap method to test with AMOS software. Using the Bias-corrected and Percentile method with 5,000 replicate samples, if the upper and lower bounds do not include zero values in the 95% confidence interval, it indicates that there exists significant mediating effect.

Test for mediating effects of team affiliation

The mediating effect of team affiliation between social needs and meaningful sports consumption behavior is significant, with an indirect effect of 0.036, excluding 0 (0.009, 0.086) at 95% confidence interval and value of $p < 0.05$. Meanwhile, the direct effect of social needs on meaningful sports consumption behavior is significant, with a direct effect of 0.269, excluding 0 (0.175, 0.375) at confidence interval. It indicates a significant partial mediating effect of team affiliation in the influence of social needs on meaningful sports consumption (Table 4). Therefore, hypothesis H8 is supported.

Test for mediating effects of self-esteem

The mediating effect of self-esteem between social needs and meaningful sports consumption behavior is significant, with an indirect effect of 0.073, excluding 0 (0.018, 0.145) at 95% confidence interval and value of $p < 0.05$. Meanwhile, the direct effect of social needs on meaningful sports consumption behavior is significant, with a direct effect of 0.234 and confidence interval not containing 0 (0.124, 0.342). it indicates a significant partial mediating effect of self-esteem in the influence of social needs on

TABLE 4 Test results of mediating effect of team affiliation.

Paths	Effect value	Boot SE	*p*	Bias-corrected 95% CI	
				Lower	Upper
Social Needs—Team affiliation—Meaningful sports consumption	0.036	0.018	0.003	0.009	0.086
Direct effect	0.269	0.050	0.000	0.175	0.375

TABLE 5 Test results of mediating effect of self-esteem.

Paths	Effect value	Boot SE	*p*	Bias-corrected 95% CI	
				Lower	Upper
Social Needs—Self-esteem—Meaningful sports consumption	0.073	0.032	0.008	0.018	0.145
Direct effect	0.234	0.050	0.000	0.124	0.342

influence meaningful sports consumption therefore hypothesis H10 is supported (Table 5).

Discussion

Discussion of results

To explore the cause that drives consumers to conduct meaningful sports consumption behavior, this paper uses empirical analysis to discuss how the social needs of consumers influence their meaningful sports consumption through the mediating effect of team affiliation and self-esteem motivation. The discussion of the result is as follows.

Social needs and meaningful sports consumption behavior

It was indicated in studies that social needs of individuals can influence their behavior. For example, higher levels of social existence will encourage higher personal motivation to interact with others. The stronger the emotional affiliation in a virtual social network, the stronger the individual's intention to use it (Cao et al., 2013). Madupu (2006) also pointed out that online sharing economy platforms have economic and social attributes, thus consumers can satisfy their social needs for belonging and identity by participating in virtual communities (Madupu, 2006). In the field of green consumption research, consumers' social needs can significantly influence their attitudes toward energy-efficient products and their willingness to repurchase (Wang and Li, 2021). In the sports research field, encouraging social interaction in sports consumption can contribute to satisfying sociability needs by emphasizing a range of social values such as teamwork and peer camaraderie in sports (Kim and James, 2019). In this study, social needs also positively influence consumer behavior in sports consumption, which is consistent with the findings of previous studies. However, unlike previous studies, this paper further confirms that social needs can not only influence consumers' general behavior but also influence consumers to take meaningful sports consumption behavior. This is reflected in the fact that individuals are increasingly concerned about the meaningful value behind sports consumption. Meaningful sports consumption provides consumers with an mix of experiences that satisfy their more diverse and deeper social needs.

Social needs and consumer team affiliation, self-improvement, and self-esteem motivation

Previous research has shown that market orientation is gradually shifting from providing customers with core products to providing higher consumer value, in which the value gained from the customer-enterprise partnership is an essential factor influencing customers' sense of affiliation to the company (Liu, 2008). In studies of sports consumption, personality traits such as the arousal needs of sports spectators significantly affect individuals' motivation to affiliation to a team (Donavan et al., 2005). This study also confirms the influence of social needs on team affiliation motivation in sports consumption context from the perspective of individual needs. Self-improvement motivation is an intrinsic drive spawned by consumers to satisfy the need for self-actualization in the social needs (Ford, 1991), which helps individuals to establish a good impression and gain positive recognition from others in social interactions (Chu et al., 2019). The same relationship between social needs and consumer's self-improvement is confirmed again in this study. Unlike previous studies, this paper confirms that the social needs of sports consumers can significantly influence their self-improvement motivation in a new context, that is sports consumption. When individuals are in a consumption situation where they participate alone, the conflict between unmet social needs and the social attributes of experiential consumption can cause consumers to experience negative emotions such as loneliness, despair, and embarrassment, thus reducing their self-esteem (Li et al., 2021). Self-esteem, respect and ambition are key motivators in sports consumption associated with achievement need satisfaction (Funk et al., 2016). The relationship between social needs and self-esteem is also verified in this study. The difference in this study is that the relationship between social needs and self-esteem motivation also

holds in the context of sports consumption. That is, the social needs becomes an antecedent variable affecting the level of consumer self-esteem motivation when sports consumption behavior is given more meaningful value.

Team affiliation, self-esteem motivation and meaningful sports consumption behavior

Previous research has shown that pride in the hometown team among fans from the same geographic region is an essential factor in initially identifying with a group. Pride in the hometown team reflects consumers' affiliation attachment to their hometown, thus this motive of belonging can influence the propensity of sports fans to identify with the group they support (Ko et al., 2017). This sense of attachment to the team or national pride will encourage consumers to continue watching the game (Zhang et al., 2016; Widjajanta et al., 2018). This study further confirmed the sense of affiliation can induce consumers' consumption behavior. Differently from previous studies, this paper further suggests that consumers with solid team affiliation motivation are more likely to engage in meaningful sports consumption behavior, besides common sports consumption.

Individuals with high self-esteem motivation see themselves as fully integrated with the team they support. The negative emotions associated with the team's failure have a low impact on their willingness to continue participating in consumption (Bizman and Yinon, 2002). In other consumption domain studies, self-esteem motivation can significantly influence consumers' conspicuous (Souiden et al., 2011; Widjajanta et al., 2018) and status (Liu and Li, 2022) consumption behaviors. Accordingly, consumers with high self-esteem motivation no longer seek positive emotional experiences or the practical and functional value of the goods they consume but rather a mix of emotional experiences or the symbolic and meaningful values behind the goods they consume. The finding of this study is consistent with previous research that individuals' self-esteem can impact their consumption behavior. However, different from the previous research, this paper further suggests that the impact of sports consumers' self-esteem motivation on consumption behavior also exists in the meaningful sports consumption domain.

Self-improvement motivation and meaningful sports consumption behavior

Study has confirmed that there is an association between self-improvement motivation and meaningful sports consumption behavior (Jang et al., 2021). However, this study confirms that in the context of Chinese sports consumption, self-improvement motivation does not significantly influence meaningful sports consumption behavior. The root cause of this phenomenon may lie in the unique traditional Chinese. Western countries are more interested in conquering nature, pursuing faster, higher, and firmer on the playing field, and showing the value of transcending oneself and nature. In contrast, traditional Chinese sports culture considers man and nature to be in a harmonious and symbiotic relationship, emphasizing on emotions and respecting moral concepts, which weakens sports' competitive nature and emphasizes the value of righteousness over profit. The Western rational way of thinking is based on the spiritual connotation of competition and transcendence. This cultural concept of survival, improvement, and perfection in competition makes the more robust the motivation for self-improvement, the more meaningful sports consumption behavior can be generated. In contrast, the Chinese intuitive way of thinking is based on the value pursuit of "harmony" and "unity." This cultural concept of sports, which emphasizes the cultivation of health and mind and weakens the competition for conquest, makes the self-improvement motive do not influence Chinese sports consumers to produce meaningful sports consumption behavior.

Mediating effects of team affiliation and self-esteem motivation

Social needs are a state of organismic deficiency that recurs periodically, which can be achieved through participation in meaningful activities (Nezlek, 2022). Meaningful sports consumption behavior can satisfy this particular need. In this satisfaction process, the individual's motivation to achieve the team affiliation to the nation or territory and the pursuit of self-esteem motivation play a significant mediating role. When sports fans psychologically associate themselves with their local sports teams, they form an "imaginary intimate relationship" with the team, in which social values are experienced through this relationship (Greendorfer and Bruce, 1991). When this kind of sports fans cheer for the same team, the sense of affiliation experienced through various direct or indirect social contacts can positively impact the individual's subjective well-being (Kim and James, 2019). In this sense, meaningful sports consumption experiences can satisfy team affiliation motivation. Self-esteem motivation arises from an individual's self-concept that gradually develops during socialization, which can influences the initiative an individual takes when adapting to society (Sherbourne and Stewart, 1991). The self-esteem gains of such sports fans often come from a sense of identification with the team and a sense of affiliation, in which their own value will be reflected through the meaningful value in meaningful sports consumption.

Past research on conspicuous consumption has confirmed the partial mediating effect of self-esteem between economic status and conspicuous consumption tendencies (Yuan, 2011), in which social media use can increase individuals' self-esteem levels and further enhance consumers' tendency to engage in conspicuous consumption (Widjajanta et al., 2018). Team affiliation motivation has been studied in the domain of how users behave in virtual communities (Sutanto et al., 2011), where the social value perceived by users when participating in virtual communities positively influences community users' sense of affiliation, in which the emotional attachment between users and the community further positively influences users' willingness to participate (Zhao and Liu, 2018).

This study further confirms the mediating effects of self-esteem and team affiliation motives on consumption behavior in

the context of meaningful sports consumption. It verifies the existence of partial mediating effects of self-esteem and team affiliation in the process of social needs to influence meaningful sports consumption behavior.

Theoretical contributions

This paper focuses on the internal mechanism of meaningful sports consumption formation. This paper develops a theoretical model for meaningful sports consumption behavior from the perspective of social needs, verifying the mediating role of team affiliation and self-esteem motivation. This study explains the essential internal dynamics in forming meaningful sports consumption, further developing the research on meaningful sports consumption. The specific theoretical contributions are as follows.

First, this study enriches existing sports consumption research by discussing the issue of meaningful sports consumption. Although research on meaningful behavior has emerged in several disciplines, including psychology (Winegard and Deaner, 2010), journalism and media (Hall, 2015), and sociology (Bartsch et al., 2018), the concept of meaningful consumption has been grossly neglected in the field of sports management. Most sports consumption research has focused on the hedonic aspects of sport consumption (Biscaia et al., 2012), neglecting the component of meaningful sports consumption. The newly emerged research on meaningful sports consumption only discussed the impact of this behavior on consumers' emotions, motivations, and behavioral outcomes (Jang et al., 2021). This study takes meaningful sports consumption as the objective of research, discussing the formation mechanism of "meaningful sport consumption behavior" from the perspective of consumer demand, finding consumers' social needs can induce their meaningful sports consumption behavior, in which team affiliation and self-esteem motivation plays the mediating role. This study introduces new research objects into sports consumption behavior, further enriching the study in this field.

Second, this paper further enriches the research object of social needs by exploring the influence of social needs on meaningful sports consumption behavior in the field of sports consumption. Current research on social needs has focused on the fields, such as children's cell phone addiction (Suki, 2013), green consumption (Wang and Li, 2021), public service development (Yu, 1992), and virtual community participation (Kong and Zhao, 2018). Most studies on social needs have only concerned the impact of social needs on general consumption behaviors, in which its impact on meaningful consumption behaviors was neglected. While this study explores the impact of social needs on meaningful consumption behavior, particularly meaningful sports consumption behavior, which enriches the study of social needs by introducing a new research object.

Finally, this paper further expands the research scope of meaningful consumption by stretch it into the field of sports consumption. Meaningful consumption has been discussed in ordinary consumption domain. For example, meaningful consumption is seen as a systematic symbolic manipulation behavior (Baudrillard, 1988), where people are keen on a commodity brand because of the pursuit of ideological values within the symbol, which may be symbolic meanings such as status, wealth, and taste. Meaningful consumption behavior has been effectively explored in the green product consumption filed, where the environmental attributes behind consumers' consumption of energy-efficient products are given some moral significance (Wang and Li, 2021). In media consumption, people watching sad movies can experience more complex emotional reflections of bitterness, introspection, and compassion, reflecting a deeper insight into the human condition and a broader understanding of the meaning of life (Oliver and Raney, 2011). Meaningful sports consumption behavior is seldom discussed separately in the research on meaningful consumption. This paper enriches the research object of meaningful consumption by introduce meaningful sports consumption behavior into this field.

Conclusion

This study examines the causes of meaningful sports consumption behavior among sports consumers from the perspective of consumer demand motivation and draws the following conclusions from the above findings.

First, as a higher level of need for individual growth and development, social needs can significantly and positively influence consumers to produce meaningful sports consumption behaviors. Second, social needs significantly affect consumer motivations for team affiliation, self-esteem, and self-improvement. Third, different consumption motives are intrinsic to the generation of different consumption behaviors. The generation of meaningful sports consumption behaviors by sports consumers is mainly positively influenced by individual team affiliation and self-esteem motives. At the same time, self-improvement motives that only emphasize individual development do not significantly influence consumers to produce meaningful sports consumption behaviors. Fourth, social needs can further influence consumers to produce meaningful sport consumption behaviors through the mediating role of team affiliation and self-esteem motivation.

Practical recommendations

1. Companies in sports business should pay attention to consumers' meaningful sports consumption behavior and strengthen this concept in sports consumption. The current consumption structure of residents has been upgraded from material consumption, actual consumption, and developmental consumption to comfort consumption, pleasure consumption, and health consumption. Sports

enterprises should actively analyze the drive behind the phenomenon of meaningful sports consumption. For various sports consumption, such as fitness, watching games, buying sports equipment, etc., there is not only one kind of value for them. However, its original "meaning" is replaced by a new meaning according to the needs and desires of consumers after combining it with their daily lives. Therefore, the products or services enterprises provide should be based on consumers' actual needs and motivations and provide consumers with more sports consumer goods to meet their value-seeking.

2. Companies in sports business should meet consumers' social needs and improve the meaningful value of their goods. The phenomenon of meaningful sports consumption shows that it is hard to meet the comprehensive needs of sports consumers through sports goods for material survival or functional value. Therefore, sports enterprises should take the social needs of consumers into consideration and realize the enterprise's long-term development by satisfying the varied emotional experience or meaningful value of consumers in the consumption process.
3. Companies in sports business should improve the team attribute value of sports goods to enhance consumer stickiness between customers and enterprises. Consumer team affiliation motivation is one of the critical motivations influencing consumers to engage in meaningful sports consumption behavior. Consumers with such motives tend to have a strong sense of national patriotism. Therefore, event operating companies should highlight more national and regional characteristics in the layout of venues and pre-game publicity to create an intense home country atmosphere.
4. Companies in sports business should strengthen self-esteem features to its products or service to increase consumers' willingness to consume sustainably. When consumers establish and maintain self-esteem connections with sports teams, they are more likely to attend future games and purchase peripheral merchandize. Therefore, for event organizers they should foster this connection through pre-game and post-game activities participated by coaches, athletes, and fans. In addition, dedicated areas should be provided within the event venue for such loyal fans and provide more detailed services to enhance or sustain the level of consumer self-esteem. Moreover, the awakened self-esteem perception can be used to initiate season tickets and membership of the following season after the season ends.

Data availability statement

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

Author contributions

WZ: conceptualization. GK: draft writing. WC: data collection. DH: data analysis. ZL: project administration. XZ: resource provision. All authors contributed to the article and approved the submitted version.

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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.

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Domesticating the condition: Design lessons gained from a marathon on how to cope with barriers imposed by type 1 diabetes

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Through analytical autoethnographic analysis of marathon preparation, this study examines challenges faced by people with Type 1 Diabetes (T1D) who engage in high-performance sports. Autoethnographer and second-person perspectives (T1D runners, family members, and health providers) were collected through introspective activities (autoethnographic diary and in-depth interviews) to understand the T1D runner's coping experience. Six insights involved in T1D self-management were identified and analyzed with reference to related design tools (prototyping, archetyping and journey mapping). Finally, we conclude with a discussion of how endurance physical activity (PA) such as running helps to "domesticate" T1D, a term coined to reflect the difficulties that T1D presents for PA accomplishment and how T1D runners' experiences give them an opportunity to overcome PA barriers promoting physical culture and enriching further health psychology studies.

KEYWORDS

type 1 diabetes, health psychology, autoethnography, physical activity, coping mechanisms

Introduction

Type 1 Diabetes mellitus (T1D) is a chronic disease affecting children and adults (Diaz-Valencia et al., 2015). T1D incidence is increasing worldwide (Mobasseri et al., 2020). Regular physical activity (PA) in T1D patients improves cardiorespiratory fitness, vascular function, and blood lipid profile (Mobasseri et al., 2020). PA is also essential for blood glucose regulation and contributes to psychological well-being (Edmunds et al., 2007). In people with T1D, PA might involve complex interactions between human and non-human

actors (i.e., patients integrating real-time blood glucose monitoring devices) embedded in networked technologies that shape individual experience.

Despite the positive effect of regular PA, only 17.8% of T1D patients are active. Approximately ~60% of T1D patients do not perform the minimum recommended exercise (Bohn et al., 2015). This lack of PA has been associated with six main barriers to carrying out exercise such as fear of hypoglycemia (Brazeau et al., 2008), insufficient time, deficient access to facilities, absence of motivation, issues around body image, and a general scarcity of knowledge around PA management (Brazeau et al., 2008; Lascar et al., 2014). These impediments to PA accomplishment call for a need to explore new knowledge production sites beyond the medical disability model. From a disability model, individual cure is conceived as the desired future for disability (Krafer, 2013). In contrast, critical engagement, such as the approach proposed by feminist science theory, allows for careful analysis of intimate lived experiences (Forlano, 2017). Thus, critical engagement highlights how T1D impairments are not disabling, even while social environments continue to have an influence on patient care.

Higher exercise intensity leads to a higher risk of hypoglycemia (Adolfsson et al., 2018). This risk is even higher for those engaged in endurance PA, such as athletes – mainly runners – who have an increased trend to lower glucose levels (Graveling and Frier, 2010). In this regard, diabetes-specific barriers to PA, such as hypoglycemia, cannot be addressed by improving patients' external conditions (as in responses to other patient needs, for example, through improved urban design or addressing visual impairments). Rather, such barriers must be handled by the T1D individual and through self-care management, with the individual solely responsible for any health consequences. Recognizing this, design in health – emerged as a facilitative system to shift toward person-centered care (Pfannstiel et al., 2019, Chap. 3), has been fruitful in developing methods and devices that help users to address their diabetes, especially people engaging in high-intensity PA. Design tools are useful for collecting user-centered research data, synthesizing and analyzing information, communicating results, and designing implications (Martin and Hanington, 2012, p. 6). For example, social identity map, a chart that integrates the position of an individual in the society (Jacobson and Mustafa, 2019), and paper diaries, a document to maintain recordings about events in their life (Weil, 2006), are design tools useful to be self-reflexive around itself and social environment in which PA and T1D are immersed. Journey mapping is also a design tool that helps visualize and illustrate daily activities and can facilitate timely healthcare and promote proactive delivery of patient-centered palliative care. In the T1D context, Riddell has proposed mapping the T1D athletes' experience (Riddell et al., 2020) that is beneficial to understanding the decision-making process of chronic diseases. As a whole, these design tools bring qualitative data that can facilitate the comprehension of variables affecting T1D training.

In addition, devices for continuous glucose monitoring (CGM) allow an individual to record glycemic variability, something that must be carefully supervised during (and for hours following) PA performance (Tagougui et al., 2019). Thus, data from CGM, expressed by the insulin pump interface as line charts that show the instant glycemic situation, as well as percentage of time in which the blood glucose levels are within the clinical recommended range or Time in Range (TIR, glucose levels 70–180 mg/dl in more than 75% of readings; Battelino et al., 2019), are very useful for user decision-making.

Furthermore, studies in controlled environments have shown the benefit of CGM in avoiding glycemic excursions in people with T1D who participate in sports (Riddell and Milliken, 2011). Evidence from real-life conditions, however, has been studied less and has been restricted to established exercise protocols (Abdulrahman et al., 2018). Such studies are also more complex, even the same PA may have a different impact on glycemic control when performed outside the laboratory (Aronson et al., 2020). There is evidence of how PA can negatively impact glycemic control; however, people with T1D who perform vigorous PA in daily living conditions have been found to achieve adequate glycemic control on training days (Abdulrahman et al., 2018; McCarthy et al., 2020). Thus, it has been proposed that consensus standard targets for CGM be more flexible for training and competition days (Riddell et al., 2020) with TIR recommendations on lower percentages. Hence, athletes should aim for >70% of TIR instead of >75% (Bingham, 2019).

Various design efforts have sought to improve glycemic control, including technological assets and equipment for CGM measurement. However, most people with T1D are still unable to reach a recommended 150 min of moderate-vigorous PA per week (Sallis et al., 2015), calling for a new way to understand T1D people's needs and practices. In this regard, T1D runners comprise an interesting group for a deeper study to understand how T1D people struggle to accomplish PA goals, perhaps the hypoglycemia risk. Moreover, ethnographic approaches are relevant here since they focus on observing runners as actors who are developing self-care strategies for T1D management.

Combining realistic medicine (Inns and Mountain, 2020), which places the patient at the center of a shared decision-making process, with a user-centered design view can help us understand how T1D people cope with PA barriers, while also recognizing that one-size-fits-all approaches to health and social care are typically not the most effective path for the patient (Chief Medical Officers NHSS, 2017). Human-centered design emerged from the field of industrial design (Bhattacharyya et al., 2019) and has sought to enrich perspectives on self-care in chronic conditions, developing significant patient-centered solutions, alleviating hypoglycemia fear, and boosting confidence between others (Kanstrup et al., 2015; Groeneveld et al., 2018). Such insights from the field of design offer innovative and powerful perspectives to help solve health issues that influence self-care.

Self-care is an ongoing process adapting the self (both mind and body) to new technologies. Integrating information that is wirelessly being generated, sent, and shared between devices, creates a highly specific and unique complex scenario for each

patient. In this regard, medical practitioners are called to improve patient care by developing a more personalized approach (Choi et al., 2020). Also, integrated psychosocial care is recommended with the goal to provide collaborative, patient-centered medical care to all people with diabetes to optimize health outcomes and health-related quality of life (Young-Hyman et al., 2016).

Most technological advances developed as tools for better T1D self-care are mainly design artifacts, such as portable blood glucose meters, insulin pens and pumps, enabling improvements in diabetes management. However, technology-based self-care implies creating new interfaces between medical devices and the patient. This creates dependencies and can add to the user's management burden. The complexity of combining and monitoring quantitative measurements, data transmission, and phenomenological lived experiences generates laborious practices, also known as "data rituals" (Forlano, 2017). Under endurance PA, data rituals can also include nutrition information, insulin sensitivity and kinetics, among others (Colberg et al., 2015). The latter adds further complexity to the challenge of processing all these data.

Even though data displayed from devices are important resources for self-management, devices tend not to match the exercise-specific requirements of PA. For example, closed-loop systems (the automated insulin delivery technology) do not allow users to register what is called "uncovered carbohydrates" that active people with T1D take without insulin bolus to avoid hypoglycemia during PA (Zaharieva et al., 2020). Some users even use interfaces to adapt them to their needs.

Thus, we can see a T1D individual engaging in PA as a "continuous data integrator." Building a system for optimum patient care, such as software integrating into hardware, requires understanding the strategies that underpin these processes. Crucial here is integrating the role of design, which comprises efficiency, flexibility, development time, problem-solving and connecting diverse functions (Bohemia, 2002). From a diabetes perspective, problem-solving is related to a learned behavior that includes generating a set of potential strategies for problem resolution, selecting the most appropriate strategy, applying and evaluating the effectiveness of the strategy (Mulcahy et al., 2003). Problem-solving is also an essential skill for effective self-management in facilitating diabetes goal-setting (AADE, 2020) and improving individual HbA1C levels (Hill-Briggs and Gemmell, 2007). When individuals succeed in solving their self-identified problems, they gain confidence in their ability to handle future challenging situations (Kolb, 2021). However, approaches to solving complex issues such as minimizing T1D barriers to PA (and building resilience) have not been explored from a research-through-design perspective.

To address this gap, the current study is a human-centered research project, with users as active participants and creators of knowledge (Ku and Lupton, 2020). We aimed to understand the factors that influence the experience of a person with T1D to reach a high-performance sports goal through autoethnographic analysis of the preparation of a marathon as a case study that allows illustrating how to overcome the barriers that the condition of diabetes imposes for the realization of this type of physical activity. We examined the importance of self-reflection and personal experience in developing more effective design strategies. We also applied design tools as research methods to collect and communicate information on personal challenges that a T1D individual has to overcome to complete a marathon. In this research process, design operates as a method to generate knowledge requiring praxis, exploration, and self-reflection (Müller, 2021, pp. 21–29). We conducted an analytic autoethnography of the marathon preparation in order to (i) show PA impact on diabetes management and (ii) to gain a better understanding of intimate personal practices that a T1D person has to go through to achieve a high-performance sport goal, mainly avoiding hypoglycemia. Our findings were analyzed by integrating determinants of health such as emotional (negative mood, stress, and anxiety), medical care (diabetes management and patient empowerment), environmental (quality and friends support, gender influence), and psychosocial factors to evaluate their effect on PA performance and self-care (Anderson, 2006; Young-Hyman et al., 2016). Finally, the study was also guided by constraints – further drawing on design research that highlights how constraints can push abductive thinking (Stickdorn et al., 2018) and boost creativity.

Methodology

Participants

A total of 15 subjects over 18 years old were enrolled for this study. Autoethnographer (main study subject) and 5 more runners (second-persons) with at least 5 years from T1D diagnosis were recruited. In addition, 4 T1D subjects with other sports expertise, 3 diabetes health care professionals, and 2 family members of the main study subject were also recruited to complement data triangulation (Table 1). The study considered medium and advanced runners with a training volume of over 21.7 ± 5.3 miles a week and more than 6 ± 3.2 h weekly training, according to categorization from runners' profiles analyzed by Besomi et al. (2018). Since most of the T1D community are still members (regardless of their age) of Fundación de Diabetes Juvenil de Chile (Chilean Juvenile Diabetes Foundation) and Corporación de Ayuda al Niño y Adolescente con Diabetes (Corporation for Aid to Children and Adolescents with Diabetes), these 2 institutions also assisted with recruitment. This study was developed during 2020–2021 and was approved by the Social Sciences Ethical Committee at Pontificia Universidad Católica de Chile. All participants signed informed consent for interview, data collection and analysis. Due to the exploratory and qualitative nature of this study, the sample selection was emergent (taking sampling decisions according to the analysis of first deep-interviews; Cohen and Crabtree, 2006).

TABLE 1 Characteristics of subjects enrolled in this study.

Subject[#]	Sports	Gender	Age	Years of T1D diagnosis	Profession
1	*Runner (Main Subject of Study)	Female	42	39	Designer
2	Runner	Male	31	10	Sales Rep
3	Runner	Male	55	42	Chemical Engineer
4	Runner	Male	48	18	Civil Engineer
5	Runner	Male	42	33	Business Administration
6	Runner	Female	33	10	Business administration
7	Sprinter	Female	23	10	Business Student
8	Recreational	Female	40	33	Public Relations
9	Swimmer	Male	20	5	College student
10	Rugby player	Male	27	26	Civil Engineer
11	Recreational	Female	38	NA	Diabetes Nurse (Health care provider)
12	Recreational	Female	35	NA	Diabetes Psychologist
13	Runner	Male	52	NA	Sports Medical Nutritionist
14	Pilates	Female	67	NA	Autoethnographer Mother (Artist)
15	Athleticism	Female	18	NA	Autoethnographer Daughter (Student)

*Autoethnographer.
[#]1–9 are subjects living with diabetes, 10–15 are second persons not living with diabetes.

Methods

This study uses a human-centered design-focus to understand decision-making in endurance PA in the context of a chronic condition such as T1D.

T1D is a condition that requires numerous, thoughtful decisions and 'constant self-care behaviors' (Abdoli et al., 2020) that increase when performing PA. A strategic design management approach helps integrate this complex process, examining design as a new paradigm to arrive at general ideas and methods for enhancing management efficiency (Best, 2006). We focus on identifying those elements in which design can help create sustainable strategic advantages (Borja de Mozota, 2003). For example, by allocating creative assets to communicate the user's problem-solving strategies, designers may use visualization skills to engender behavior changes (Cooper et al., 2011); useful for a T1D person interested in performing PA. Moreover, introspection is relevant to design as a means for understanding individual experiences (Xue and Desmet, 2019). Thus, we used autoethnography and ethnography methodologies for a better understanding of the complexity of decision-making processes in PA according to experiences in T1D context.

Autoethnography

This methodology was selected as a primary method for its interpretive power and its focus on connecting the researcher's personal experience with cultural and social context as a way to analyze individual practices in more detail (Jones, 2005), helping to understand decisions and self-care behaviors during PA accomplishment.

Thus, to comprehend individual behavior health determinants during PA in T1D context qualitative data was collected through (i) in-deep Interview (interview transcripts that include autoethnographer's mother and daughter), (ii) Athlete Diary (handwritten notes and figures), (iii) Identity Mapping to understand identity construction (handwritten figures), and (iv) a perception score surveillance. To evaluate individual behavior health determinants (physical activity, glucose control and perceptions) during PA in T1D context we collected quantitative data from autoethnographer. These data included glucose monitoring (time in range) and heart rate (HR zones) parameters. Time in range (TIR) parameters simplifies the assessment of glycemic control and includes the percentage of time with blood glucose values between 70 and 180 mg/dl (ranges clinically recommended); Time Below Range (TBR), which includes the percentage of time with blood glucose values between 54 and 70 mg/dl and those below 54 mg/dl (hypoglycemia); and Time Above Range (TAR), includes the percentage of time with glycemic values greater than 180 mg/dl (hyperglycemia; Battelino et al., 2019).

Regarding HR, it was measured according to five zones relative to the maximum HR of the runner that a smartwatch can measure, and is related to PA intensity (Skinner et al., 1980). This variable refers to how the heart is beating during the exercise, measuring the athlete's effort. Thus, Zone 1 corresponds to a HR between 50 and 60% of the maximum HR; Zone 2 to 60–70%; Zone 3 to 70–80%; Zone 4 to 80–90%; and Zone 5 to 90–100%. According to their training program, each runner selects the zone that needs to be worked on to avoid overstressing their skeletal and muscular system, an event that happens when the runner is held in Zone 5 too long (Fletcher et al., 2013).

To understand autoethnographic perception of glycemic control (according to PA intensity), a quality Likert perception score (Perception score I) was evaluated in each training phase, from 1 as a negative or very poor perception (not being able to control glycemic variability) to 5 as a positive or excellent

perception (being able to control glycemic variability): "Very poor" = 1, "poor" = 2, "fear" = 3, "good" = 4, "excellent" = 5.

Ethnography

This method was used to provide further depth to the second-person's diabetes experiences in PA context, complementing the autoethnographic perspective. We recruited T1D runners, family members, and health caregivers as informants so that we could observe and analyze behavior in the 'naturally occurring conditions' that ethnography favors (Belk et al., 1988).

Qualitative data were collected through (i) in-depth interviews, (ii) Design Probe, and (iii) a Perception score Surveillance. In-deep interviews were conducted with 15 individuals. This sample included 6 runners (including the autoethnographer being interviewed by a research assistant, a strategy which was used for instrument validation); 1 swimmer; 1 sprinter; 1 rugby player; 1 recreational runner; and 2 individuals from family environments. To acquire a professional T1D view, we also interviewed 3 health professionals. Detailed questions are included in supplementary material. Design probe was conducted by 1 runner and the probe was designed to explore determinants of health such as emotional and medical care, that are important in diabetes management. This probe included testing a new sport, registering the emotions involved in the experience, and sharing methods for overcoming PA barriers imposed by T1D (done by sharing photos and text messages with the autoethnographer for 2 weeks on a mobile platform). Information gathered as part of this process included insulin intake, carbs load, PA type, time and intensity to control the participant's blood glucose response and avoid hypoglycemia. A surveillance was designed to evaluate how athletes rated their apprehensiveness about glucose levels during PA (Perception score II). Athletes rated the level of concern about their blood glucose levels during the training steps (*How much does hyper and hypoglycemia concern you in each training phase?*). Qualitative responses were coded as: "*not at all*" = 1; "*a little*" = 2; "*moderately*" = 3; "*quite a lot*" = 4; "*a lot*" = 5. Perception score II were collected from 6 T1D runners and 1 less active subject.

Procedure

This study methodology was divided into 5 phases (see "Methodology," Figure 1).

In Phase 1: Observation and Preliminary Design; it was the first observation of T1D people in the PA context that would inform posterior study design. Two-day field observation was conducted at a Summer Diabetes Camp organized by Fundación de Diabetes Juvenil de Chile in January 2020. This activity gathered T1D camp participants, team members, and health specialists; the whole group for the week totaled around 90 people. Phase 2: Recruiting; Adult athletes were recruited by social media, and with the support of T1D endocrinologists and health care providers and diabetes NGOs in Chile. Phase 3: Instrument Application; the personal athlete diary was kept throughout the whole study period. These data were recorded primarily in a written daily diary (athlete's diary) over a month, including insulin regime, food intake, training minutes and glycaemia data from training apps, food photos, and insulin pump screen information on glycemic trends. Comments were also included on each event, the diabetes management strategy used, and changes required for future exercise. Finally, the autoethnographer accomplished an introspection exercise, drawing on information design, to facilitate and systematize the data collection (and to determine subsequent training phases). The Identity Mapping was adapted from the "culture gram" (Chang et al., 2016), which visualizes self-identifiers according to multiple perspectives such as social roles, belonging to groups, and primary culture identities. The information obtained was then color-coded to see how T1D could connect with other self-identifiers. Due to the Covid-19 pandemic, in-deep interviews were conducted online. Also, the design probe was created to avoid potential Covid transmission by physical contact. Our design probe is called "adaptation process for endurance PA." Since lockdown rules did not allow for outdoor training, a second-person participant used a "stationary bike" which they had not used before. At the end of design probe data collection, autoethnographer and second-person discussed their experiences collaboratively using "visual research" (Bestley and Noble, 2016) – as an instrument for articulating processes, which involves the analysis of icons collected for a deep understanding of PA challenges and barriers. Phase 4: Data Analysis; Deep interviews (autoethnography and ethnography) were analyzed by ATLAS.ti Version 8.4.3 (1077), gathering the basis for preliminary insights, which were further analyzed with triangulation. In this study, triangulation reflects an attempt to secure an in-depth understanding of the phenomenon in question. Triangulation was addressed from the following perspectives proposed by Flick (1992), "data-triangulation" or the combination of different data sources that are examined at different times, places and persons (perception score surveillance, second-person *deep* interviews and feedbacks; Carter et al., 2014), presenting a crosstalk of points of views; "investigator triangulation," which means the employment of different observers or interviewers to control or correct the subjective bias from the individual and "methodological triangulation" or "technique triangulation (autoethnographic diary, identity map, design probe). In addition, design tools were used to communicate preliminary insights through charts, an identity map, and a journey map. Phase 5: Final insights; the insights were validated in dialog with the second-person research participants and T1D health care professionals (Figure 1).

Statistical analysis

In data triangulation, the statistical analysis was defined by the nature of the quantitative information obtained both from the autoethnographer and second person's data (Denzin and Lincoln, 2007). Since the quantitative data obtained presented numeric variables normally distributed, with perception scores being

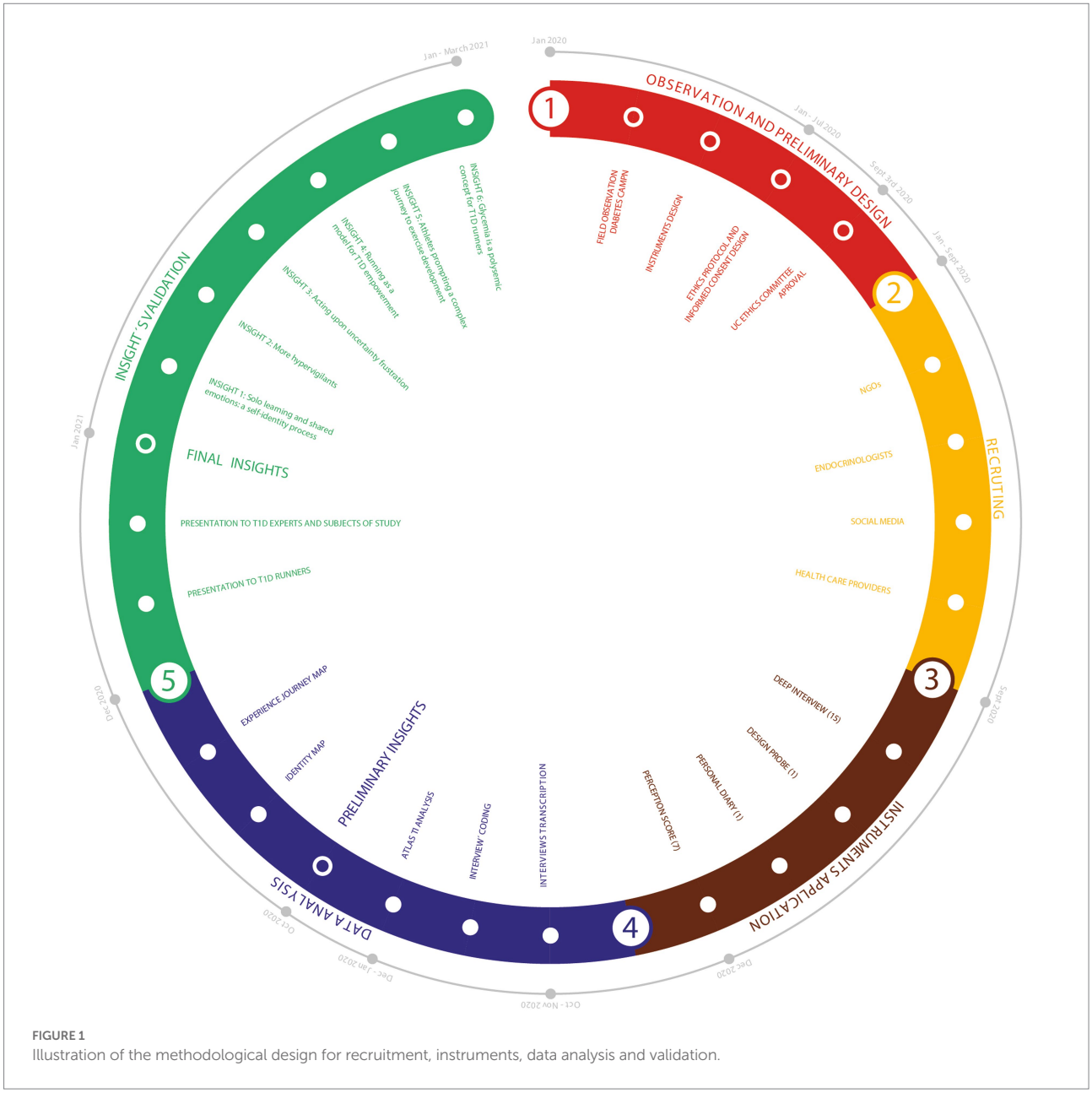

FIGURE 1
Illustration of the methodological design for recruitment, instruments, data analysis and validation.

ordinal and with no outliers found, we used *Spearman* correlation. This test was applied to evaluate if the perception of glycemic control (Perception score I) measured during training (training phase 2) correlates with HR zones, and when measure post-training (training phase 5) it was analyzed with glucose control parameters (TIR, TAR, and TBR). p value < 0.05 was considered significant. Perception score II and Training phases were graphically analyzed in seven athletes.

Results

As previously reported, glycaemia during exercise can vary inter-and intra-individually, and It depends on various factors such as exercise modality and intensity, nutritional status, time of insulin injection, or pre-exercise glycaemia level (Tonoli et al., 2012). This background complicates the scenario for T1D athletes to reach their sport goals, generating various elements to consider for decision-making before, during and after a competition or training that also involves different users' perceptions. The following insights illustrate design lessons gained from a marathon.

Solo learning and shared emotions: A self-identity process

Exercise or any deliberate practice gives the ability to choose what risk to take. In particular, running puts individuals in

considerable deliberate difficulty or "deliberate practice" of working on something that is not easy. In fact, obstacles such as any challenging task have shown to be more productive in problem-solving than hours of repetition of familiar actions (Ericsson and Harwell, 2019). However, when we add T1D into the equation, running could be considered a risk; yet despite exposure to a significant chance of adversity, it favors resilience development (Hilliard et al., 2017).

In this study, T1D people tend to be motivated to start intensive training by contextual situations associated with childhood experiences that can fuel the will to run, e.g.:

> *"I used to be good at running when I was in school, but I still remember that gym teacher telling me to slow down, to do less just because of my diabetes" (T1D Runner, 42 years old).*

Further, powerful negative emotions such as a severe car accident because of hypoglycemia *(T1D Rugby Player, 27 years old)*, or losing a T1D friend (*Autoethnographer*) prompted them to pursue endurance exercise. Similarly, positive emotions or memories can trigger intensive PA, such as a relative who instilled courage *(T1D Runner, 26 years old)*. Thus, "diabetes resilience," defined as good psychosocial and health outcomes (Hilliard et al., 2017), is not a personality trait given with the condition; rather, it tends to be built out of difficulty or risk.

These experiences help us to recognize that resilience is a multidimensional topic that involves the patient support system and strengths. As the Psychologist interviewed stated, "resilience is built considering very important psychosocial factors including education, family support and socioeconomic status; they all help to overcome difficulties and educate the patient on how to stand up after failure." Therefore, running can contribute to developing resilience, learning how to make decisions, and tolerating frustration, all of which could be considered resources to overcome T1D PA barriers and risks. Running can also help individuals to understand that no disease-based labels such as "diabetic" should restrict their possible activities.

Furthermore, a gap currently exists between the promise and the reality of diabetes care. Practical interventions to facilitate collaborative relationships and foster patient-centered practices are key to closing this gap (Funnell and Anderson, 2004). As intensive running demands the user to be constantly self-aware of health signs and to process them for decision making, a lot of time is dedicated to self-reflection. This introspection supports forms of self-discovery that help with identity development (Waterman, 2011) and which function as a resource to cope with T1D (Luyckx et al., 2008). The studied experiences showed diabetes lived from past perspectives, impacted positively on self-care activities. This was confirmed by an athlete interviewed, echoing the idea of refusing to let diabetes interfere with his sport performance. He was able to lift the highest weight of all his team, even though he had the lowest height. He not only wanted to be better, he wanted to be the best, regardless of diabetes (*Rugby player, 27 years old*).

This was also confirmed by the autoethnographer's family members, one of who said: "When you run you are not competing against others, you are on a race to beat diabetes."

To delve deeper into the idea of T1D becoming an influential part of the runner's identity, the autoethnographic identity map adapted from the identity culture gram developed by Chang et al. (2016) shows how PA challenges become a self-identifier for those with T1D (Figure 2).

> *"PA hours are a powerful time for my identity, because you only run 1 h a day, but that hour accounts for one of the activities I love the most, and it allows me to be part of an amazing group. Running also gives me a sense of purpose"* (*Autoethnographer*).

Diabetes influences and extends the hours dedicated to running and also can determine whether the sport can be developed or not. With the idea of not letting the condition undermine the athletic passion, T1D starts influencing an essential realm of identity:

> *"Diabetes started blending into my identity through running, it also moved into my work and is making me utilize my creativity as a primary self-identifier"* (*Autoethnographer*).

These findings put running (interests), creativity (multiple intelligence) and design teacher/design researcher (work) as self-identifiers (Figure 2), fixing with the concept established by Chang et al., that relates a self-identifier with knowledge, skills, competence or emotional attachment to function as a member of a group (Chang et al., 2016).

Considering T1D runners as part of a group, most of them claimed to pass through PA in the diabetes context as a solo experience because they have not had opportunities to discuss the topic of diabetes and sports. Runners sense PA as a solitary trip, even though health determinants, such as experiences and emotions are similar among these individuals, particularly those that integrate T1D self-care into a PA lifestyle:

> *"I have been very lonely; I have read a lot, but to share with someone who says these are the guidelines and look at this? No, I have developed it by myself"* (*T1D Runner, 42 years old*).

Another participant talked about a very dense spreadsheet where he registered every data that had an impact on his diabetes and helped him with his self-care (*Rugby player, 27 years old*).

Runners stated that they need additional time to include diabetes care (such as analyzing and making insulin and nutritional adjustments) into the general training routine. Hence, there are many self-observation and introspection hours that help identify the patterns and to take actions that improve diabetes self-care (so that T1D does not become a constraint on exercise).

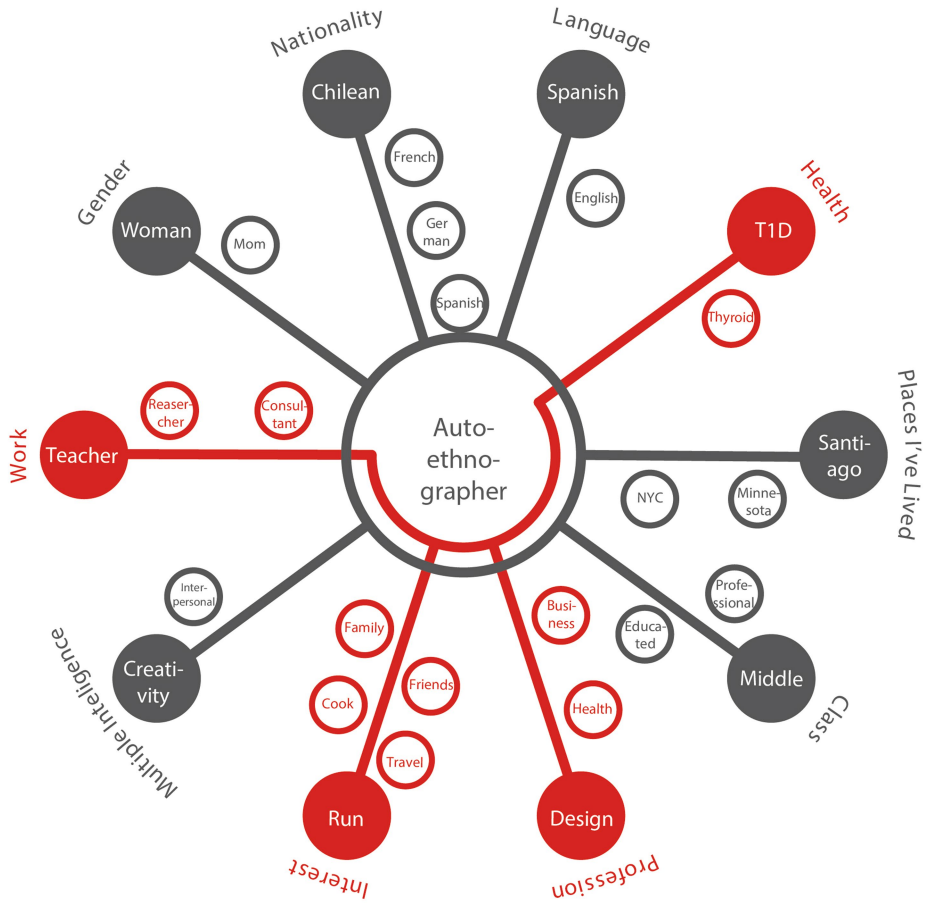

FIGURE 2
Identity map visualizing self-identifiers and social perspectives.

> *"It is like the individual extra cost you have to pay to earn the runner identity."* (*Autoethnographer*).

These declarations suggest that running improves illness integration into identity construction around diabetes acceptance.

Hypervigilance

Recommendations for psychosocial care of T1D patients involve monitoring the patient's performance of self-management behaviors and psychosocial factors impacting the person's self-management (Young-Hyman et al., 2016). When intensive PA is added, the process is more demanding, requiring frequent testing, insulin adjustment, and tighter control of glycemia that can build a sense of hypervigilance against hypoglycemia (Trief et al., 2013). With currently available technology such as insulin pumps and integrated glucose monitoring, a new set of information is available for patient use, integrated into daily living conditions as data rituals (Forlano, 2017).

With T1D, endurance training experience has to be thoroughly planned. In this study we observed that runners tend to monitor themselves 24 h a day, 7 days a week; a behavior consistent with a hypervigilant profile. In fact, some runners mention their physician suggesting "relaxing" and not watching the pump screen too frequently:

> *"What my diabetologist told me was not to look at the pump all day. what matters is the complete movie, if some points are off track, as long as they are isolated and not recurring .. no harm will be generated!" (T1D Runner, 33 years old).*

This experience resonates with other patient declarations. *"Even with a different diabetes specialist, the advice was just the same, try not to be watching the pump screen so often" (Autoethnographer).*

Hypervigilance is a behavior that involves an enhanced or exaggerated search of environmental stimuli or scans for threatening information (Rollman, 2009). It is associated with elevated or clinical anxiety levels. Within this context, glucose monitoring and data rituals can be both useful and overwhelming at the same time. Indeed, glycemia values on certain ranges not only activate insulin pump alerts, but also threaten T1D runners with a sense of fear or anger in response to data:

> *"As a runner, you certainly do not want to be interrupted while training, so whenever you check your pump, what a great feeling you get when your glycemic trend is steady"* (Autoethographer).

Particular attention should be paid to this topic. Adults with diabetes have a 20% increased prevalence of anxiety disorders than those without diabetes (Smith et al., 2013) when compared with the highest generalized anxiety disorder rates. Women, youths, people with longer diabetes duration, and those with additional medical conditions are at the highest risk (Groot et al., 2016).

Acting upon uncertainty and frustration

It can be extremely challenging for individuals to balance all the factors involved to improve glycemic control around exercise (Colberg et al., 2015). It can be even more challenging when confronted with a new PA. T1D runners interviewed stated that the idea of doing something with high metabolic demands for the first time could be scary, since there are too many uncertainties on how to avoid the risks involved. Usually, T1D people develop their strategy during PA to avoid hypo and hyperglycemia through trial-and-error and several individual attempts (Finn, 2018). However, as Perkins & Riddell state (Perkins and Riddell, 2006), running is a complicated process requiring a lot of motivation and effort from the individual and their family members; the latter may also sense the runner's difficulties, e.g.:

> "*You know what I think is what frustrates you most about running with T1D? It's when you do not know why, when you cannot tell why things happen*" (T1D Runner's daughter).

This uncertainty feeling was also confirmed by another subject who stated that she was eager to learn whether what happened to her during running was, or was not, related to diabetes. For example, when feeling more tired:

"Is this diabetes-related, or is it normal athletic exhaustion?" (Runner, 33 years old).

Besides, runners' uncertainty is nurtured by the fear caused by the unknown, such as hypoglycemia fear – thus becoming a barrier to exercise. In a study of newly diagnosed patients, hypoglycemia was feared even though some participants had never been physically active (Kennedy et al., 2018). In this study, a diabetes psychologist interviewed confirmed this background:

> *"I believe that very few [patients] have experienced severe hypoglycemia and most people are afraid of it. In addition, since patients debut with T1D, people from both their family and health care professionals speak to them demonizing hypoglycemia" (Professional 2).*

High uncertainty is a stimulus for seeking information in anticipation of future interaction (Berger and Calabrese, 1975), which could also be viewed from a design perspective: "*Design is always directed towards an (uncertain) future and helps shape it*" (Simon, 1996, p. 111).

In this regard, self-experience in the T1D running context offers an excellent opportunity to apply and test recommendations given by physicians. Hence, T1D runners try to control the uncertainty by systematizing their training routine, developing methodical records, or keeping track of their blood glucose data during training sessions. As one participant put it:

"At first, I used to write everything down, but once I got the system working, I no longer needed to keep registering information" (Runner, 50 years old).

Moreover, most of these records are not necessarily shared with each patient's endocrinologist. However, they provide informed decision-making knowledge (see Supplementary Table 1). The way in which data is displayed in the autoethnographer diary (Figure 3) shows how it can become an information design artifact that enables finding causes for the uncertainties that frustrate patients, helping T1D athletes become their own efficient caregivers.

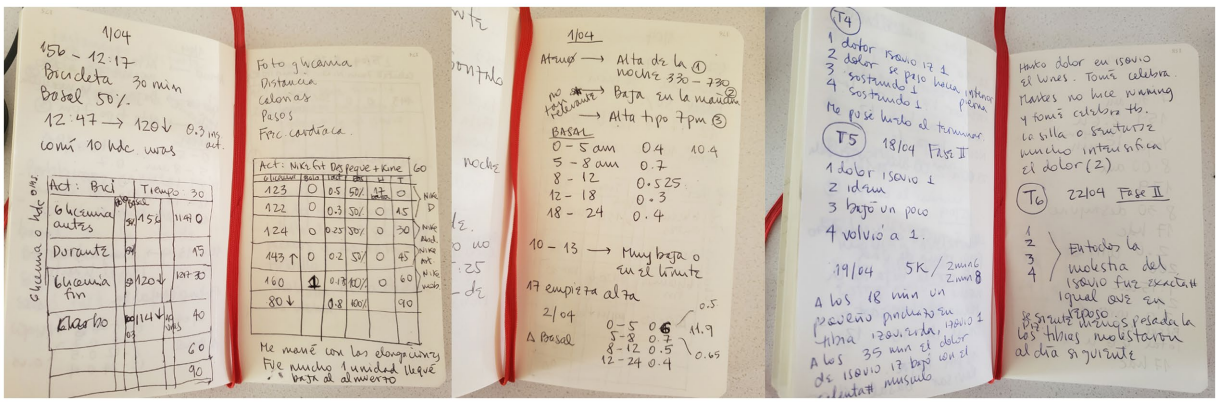

FIGURE 3
Autoethnographic diary pages showing representative notes of PA management.

Running as a model for T1D empowerment

Empowerment is a psychological state that occurs as a result of effective communication (in health care), and which acts as a determinant of consequent participation, self-management and self-care (Small et al., 2013). Furthermore, empowerment in long-term conditions has been associated with expert-patient initiatives to improve diabetes management (Wilson, 2005). In this study, T1D runners were also observed to increase their empowerment through PA accomplishment, leading to self-care practices and disease coping. These findings show that psychosocial aspects of T1D are an essential field for further study in future research.

On the contrary, emotional exhaustion and frustration with diabetes self-care behaviors refer to a negative psychological state known as "burnout" (Stewart et al., 2019). Burnout is related to diabetes distress (Abdoli et al., 2020) and individuals losing their sense of empowerment. As Abdoli et al. (2020, p. 6) states, some patients view themselves as a "slave" to blood glucose numbers because those "numbers and algorithms" were the "guiding principle" of their lives and the "key indicator of perfect diabetes management." In this study, some runners feel the constant pressure of glucose monitoring, especially during their training. When they cannot check their glucose levels during a race (for example, due to a failure of diabetes devices), they feel a relieving sensation, improving their focus on the running routine:

> "*On kilometer 3 (1.86 miles) of the Chicago marathon, I lost Bluetooth signal, which means my insulin pump could not read the continuous glucose monitor sensor transmission, giving me no chance to check my blood sugar during the rest of the race. It had happened to me before, on crowded races, there is some level of signal interference. So, I had prepared myself for it by spot hypoglycemia just checking on my body sensations and having a running protocol well thought-out and tested on 30 k (18,6 miles) runs twice before. So not being able to get any info from my pump, it had no purpose for me to be constantly checking it and for the first time my attention was set entirely on enjoying the run with an overwhelming sense of control on T1D*" (Autoethnographer).

T1D people with fewer perceived barriers to PA have greater T1D auto control (Brazeau et al., 2008) related to diabetes care. Thus, people with T1D who are able to manage PA barriers are more able to cope with other problems (Brazeau et al., 2008). In this study, runners felt they must perform several self-care conducts successfully to practice sport, which represents a major challenge for the athlete. For example, the challenge of maintaining glucose levels within range, in addition to their running goals. Although this could lead to athlete burnout, getting optimal glucose levels during workout and performance promotes beneficial disease-coping, building diabetes resilience. Running puts the T1D runner in considerable deliberate difficulty or "deliberate practice" of working on something that is not easy, impacting other aspects of athletes' social lives. For example, runners mentioned that if they can deal with a marathon's demands, they also will handle diabetes issues:

> *"When you reach a certain sport goal, such as finishing a marathon, it feels like any diabetes problem is way smaller than all you had to go through to reach the point where you are"* (Runner, 31 years old).

Hence, running raises T1D empowerment, promoting self-care with self-confidence for improving their health.

Athletes' complex journey to exercise development

T1D is a medical condition involving rigorous decision-making with constant self-care behavior (Abdoli et al., 2020). Analyzing different variables affecting exercise decision-making, this study focused on the relevant elements that define the user experience to avoid hypoglycemia using the autoethnographer's previous marathon experience. Then, a journey map was designed to visualize the runner's diabetes management strategies. This was also helpful, to showcase different possible scenarios according to glycemic levels, carbohydrates, insulin bolus and meals, ranging from the previous workout day until the post-workout, reaching the following 24 h (Figure 4). This journey map shows the network representing the challenge for athletes. Further, glucose monitoring was crucial to structure this map, highlighting glycemic levels (>240 mg/dl) or hypoglycemia (<54 mg/dl) at pre-workout (stage 1) that might influence non-running decisions:

> *"When I go running with my T1D friend and she hits a very low glycemia, I am the one who does not want to keep up and wait until her levels are up and safe again. So, it is personal. However, she feels relieved to have a low while running with me"* (Autoethnographer).

The idea of getting closer to a fixed running model for a suitable T1D self-care is tempting; however, this is not possible following realistic medical perspectives. Nonetheless, the experience map should provide an overview of what such a process entails and how to modify it:

> *"I get the idea that the next one (marathon) it's going to be easier, still challenging, but you already have a system"* (T1D Runner's daughter, 18 years).

To adapt this model of journey map for training conditions, the autoethnographer replicated training phases analysis. Due to COVID-19, the autoethnographer changed her training routine to follow confinement restrictions (and also due to a tibial stress injury), utilizing a treadmill with shorter running periods to recover. In order to have a better understanding of training phases,

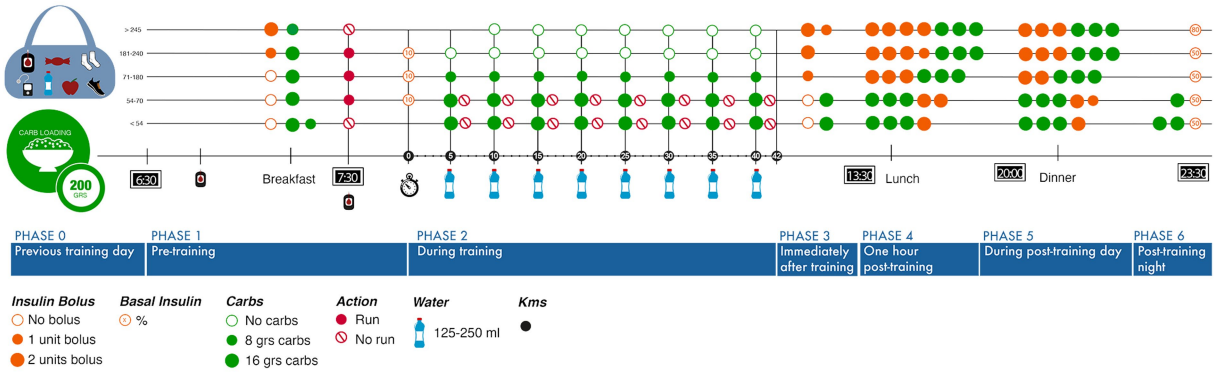

FIGURE 4
Journey map running designed according to training phases and glycemic control requirements.

a perception score (Perception score I) was assessed according to PA intensity (heart rate zone). It was observed that low-intensity running was less challenging than high-intensity running in terms of glycemic control – even though all cautions were taken with carbs loading and insulin regimen. Also, an inverse correlation was found between staying in extreme PA intensity (Zone 5) and a lower perception score of glycemic control (Supplementary Figure 1).

> "*When I saw the results, I was getting for high-intensity PA, I realized my carbs would need to be adjusted and it was time to call my nutritionist for advice*" (Autoethnographer).

Following the training phases model, achieving better glycemic control was more efficient. Thus, integrating qualitative and quantitative data is useful to improve the maintenance of glucose levels during exercise in T1D runners:

> *"My heart rate frequency and glycemic control had never been studied before, and it certainly helped me communicate my concerns to my healthcare provider about how crazy my blood sugar was going using the same insulin and carbs strategy I had used before. As he is also a runner, he easily discovered what I was doing wrong. None of these would have been possible without integrating qualitative and quantitative data"* (*Autoethnographer*).

Then, when the autoethnographer shared the journey map model with second-person participants to validate it, the subjects were able to realize the whole picture and elements that compound their training:

> "*It is amazing to visualize our process and how many decisions we need to make for something that might be so simple as running. I am impressed, and by the way, I think this makes us really cool*" (T1D Runner, 33 years old).

Therefore, data visualization of the variables involved in the T1D running experience as an integrated unit reduces uncertainty, guides the search for information, and resonates with other users—thus facilitating learning for diabetes self-care.

Glycemia is a polysemic concept for T1D runners

Polysemy is a linguistic concept related to the several possible meanings of a word. In this context, polysemy was used to understand how glycaemia levels can have different meanings according to PA training phases or personality characteristics in T1D.

Some personality traits were prominent among the T1D runners, according to the in-depth interviews applied in this study (perfectionist, methodical, resilient, self-demanding, extremist, hypervigilant, competitive, hyperactive). Some of these traits were not different from any other athlete, such as competitiveness and self-demand. However, hypervigilance, fear and perfectionism are all specifically related to T1D. Some athletes reported to their health provider that hypoglycemia fear makes them stop their training routine to avoid a low blood glucose episode:

> *"What the athlete wants is to have glycemia as normal as possible, to have optimal metabolic control, such as if they wanted to see themselves as non-diabetic persons. Being lower, you are going to be closer to normal than being high. I think it has to do with their personality. They want to be perfect, even though that is very difficult"* (Nurse).

A contradiction was found among T1D runners. Their deepest fear is hypoglycemia, being associated with anxiety and mood (Seaquist et al., 2013); yet, when the total perception score of hypoglycemia was studied, hypoglycemia had a lower score (2.5) than hyperglycemia (3.2), suggesting that T1D runners preferred low glycemic levels than to tolerate a hyperglycemic status (Figure 5A), despite the clinical risk.

> *"In my case, it scares me more, but I have to admit that I have seen myself and if you have to make me choose, I prefer a low*

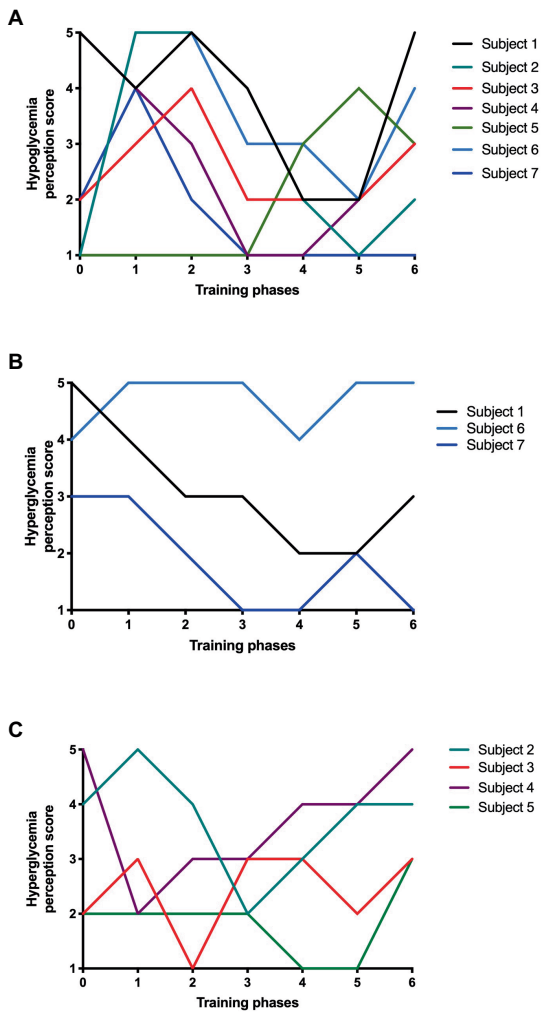

FIGURE 5
Hypo and Hyper glycemia perception score during training phases. **(A)** Hypoglycemia perception score according to training phases for all enrolled subjects (*n*=7); **(B)** Hyperglycemia perception score for women (*n*=3); and **(C)** males (*n*=4) according to training phases.

> *one to a high one… on a high, it takes two hours to get you back down, and running with a high is uncomfortable. One feels the body much heavier"* (Autoethnographer).

There is an objective clinical view of glycemic levels, but the perception of these levels changes according to the subject context. In this sense, both hypoglycemia and hyperglycemia can be polysemic, implying that glycemic data can have a different meaning according to the athlete's training phase, impacting mood and anxiety. Athletes might therefore frame different emotions evoked around blood glucose levels, but such knowledge remains vague. To address this, we studied autoethnographer perception (*Perception score I*) associated with glycemic range during exercise stages. Perception score correlated inversely with the time below range (Supplementary Figure 2). This finding suggests that positive perception is related to minor hypoglycemic episodes, which confirms the idea of fear around hypoglycemia.

It is also interesting to notice how diverse perceptions (*Perception score II*) were found for severe hypoglycemia (50 mg/dl) according to the training stage. In pre-training and training phases (Phases 0–2), the mean average score tended to be higher (2.9) than post-training phases (Phases 3–6; 2.2; see Supplementary Table 2). Hence, if hypoglycemia happens in pre-training or during training phases, the running could be compromised being much worse than after training phases.

The perception of hyperglycemia was then studied according to gender, finding that women tended to be more worried about their hyperglycemic events (Figure 5B) than men (Figure 5C). Also, hyperglycemia fear emerged as a main PA barrier element that was evident for healthcare providers:

> *"Women are much more rigorous and much more methodical in the matter of self-control, exercise, sport and being in shape. Most of the patients I recommend for psychological support are women"* (Psychologist).

Thus, athletes' perception of hyperglycemia's interference might depend on gender, consistent with the anxiety prevalence on T1D, where women are at the highest risk (Smith et al., 2013). This different gender-dependent perception reinforces the glycemic levels as a polysemic concept, which changes according to the context and intrinsic characteristics of each subject.

Furthermore, each insight generated during this study can be identified in the introspective first-person experience:

I woke up around 5 am that morning and had put alarms during the night every 2 h to make sure my glycemia was completely under control. I needed to make sure no insulin was on board for the marathon. After almost 2 years of training to get there, I certainly did not want to mess things up when they were under my control. You need to be at the marathon almost 2 h before the start to get your credentials, put your stuff on lockers, and then wait for at least an hour on your assigned spot. I had my breakfast snack with me, a plain yogurt with 10 grams of carbs, and I ate it 20 min before the start, my pump was showing a nice 109 mg/dl glycemia. I was full of anxiety. What was about to start was something I had never done before, and my dead friend's memory gave me all the strength I needed.

As we were given the go, I watched my pump and it was showing 108 mg/dl (in range, but on the lower end), so I took a "precaution" chew and started running (Glycemia is a polysemic concept for T1D runners). *The first 3 km were just wonderful, the weather was perfect and the city's cheering and its energy, the runners and the thousands of spectators were overwhelming. Before I got to kilometer 4, my insulin pump stopped showing my glycemia. The bluetooth saturation was so high because of all the sports watches that I could not get the sensor signal into my pump. Fortunately, I had trained for this since it had happened to me on the same races before, so I had practiced blind running to get to feel my glycemia while running. So, I did not panic at all, my protocol was to get 8 grams of*

*carbs every 5 k and I totally trusted the hard work, especially by my marathon runner nutritionist, that has put into getting me to where I was (*Solo ride shared emotions*). So just like that, my anxiety for data was gone (*Hypervigilant*). I had to trust in my body and follow the protocol. For the first time ever, my mind was only concerned about enjoying the run, no alarms, beeps, or demands from the pump, my diabetes was completely silent, giving me no burden at all.*

*On km32, my quads felt different, heavier, a feeling of dizziness came in and I could figure out what that could mean, it felt kind of hypoglycemia, but I wasn't quite sure. Just in case, I took an extra chew, 8 grams of carbs, and kept going (*Acting upon uncertainty*). Only after the marathon I learned about hitting the wall, which refers to depleting the stored glycogen and the feelings of fatigue and negativity.*

*I crossed the finish line at 4:00 h, my exact goal. Exhausted, I immediately asked for a medical assistant to check my glycemia, the reading was 232 mg/dl. Goal accomplished both as an athlete and as a person with T1D (*Glycemia as a polysemic concept*), I felt enormously proud, this wasn't competing with me or with others, this was a way to show I was in control of my condition like I had finally domesticated Type 1 Diabetes* (Running as a model for T1D empowerment).

Discussion

This study shows how running boosts resilience in T1D people, findings that are consistent with other investigations, as stated by (Hilliard et al., 2012), in which traumas and challenges mobilized and motivated patients, impacting positively on T1D management and self-care. To understand running performance under T1D condition, a proven beneficial design tool for patients and health care was utilized to create a journey map specific for runners. Previous road maps have been reported for Type 2 diabetes and T1D people mainly to assist clinicians in reaching glycemic control goals of their patients (Jellinger et al., 2007) and for self-management education (Der Molen et al., 2017). In this study, the journey map proposed is applied to a PA context, showing phases and variables that need to be considered and controlled by an athlete with T1D. These are aligned with what Riddell et al. (2020) showcased for a training or competition day. In addition, shared emotions between T1D runners (with respect to journey map visualization) suggest that the journey map tool could be useful for self-management not only for the running community interviewed for this study but also for the T1D community worldwide.

Since it can integrate information in a coherent manner, the journey map could also enable patients to become active learners who seek out information and are assertive in their pursuit of understanding and new information (Kolb, 2021). As stated by Fisher et al. (2005), behavior changes and improved problem-solving skills can be facilitated by learning from previous choices and then revising plans based on information gained. From the health care team perspective, the journey map could be aligned with the model for self-care behavior presented by Kolb (2021), because it helps track more variables, sets which information to track, evaluates and suggests the tracking frequency, in order to prevent data overload and decrease time burdens associated with interpretation.

Considering the journey map as a design tool to address a marathon training experience, it could help to "domesticate" T1D, a term that is proposed to understand how this condition can be handled. Domestication is a complex concept related to human social evolution that concerns communicational, cognitive and emotional plasticity, improving behavior, living in community and detriment of aggressiveness (Shilton et al., 2020). In this line, diabetes can also be considered aggressive (for example: during hypoglycemia and hyperglycemia), when it starts screaming, through beeps and sounds from CGM devices, or what Forlano (2017) describes as distressing moments. Continuing along these parallel lines of thought, experimental results suggest that *tameness* (Agnvall et al., 2015) and a *less aggressive* behavior and appearance drive animal domestication (Kaiser et al., 2015), improving their approach to humans.

In this sense, T1D could be compared with an animal that must be domesticated, and within this process, exercise may be a helpful resource as a routine activity that gives more chances to adapt strategies to tame aggressive diabetes behaviors. In this study, when subjects are involved in running, they show what could be considered as domestication practice over their condition when they describe a feeling of empowerment *over* T1D. This possibly relieves the burden of operating in chronic diseases, that has been related with *a slower speed of movement about barriers over which one has little to no control and might need more time to accomplish something or to arrive somewhere*" (Krafer, 2013, p. 45). Hence, T1D people training for a marathon can learn to anticipate diabetes outcomes and patterns because it gives plenty of exposure by trial and error, and enhances problem-solving processes – which involve problem identifying, alternative solutions development, solution selecting, implementation and evaluation (AADE, 2020). These phases can be facilitated by the journey map proposed in this study as a tool to help the domestication process of T1D.

Further, domestication is a process that involves the formation of a mutualistic relationship between human beings and the environment (Price, 1999) and is crucial to boosting adaptation. It is possible to expand this notion to diabetes through the identity map construction presented in this paper, where running promotes the merging of T1D with other identity dimensions, similar to what Chang et al. (2016) show through the culture gram to interconnect culture and identity. In the same manner, when running and T1D are considered as more than just single identity trajectories, they can be viewed [as Wenger (1998) put it] as a nexus of multi-membership that could connect condition and identity. Similarly, the identity map contributes to illness acceptance, as a concept related to the lack of negative reactions and emotions connected with the disease (Cybulski et al., 2017). In this line, low diabetes acceptance is more related to insufficient diabetes self-care and self-management, with poor glycemic control (Schmitt et al., 2014; Oris et al., 2016). The marathon experience and training involved served to integrate diabetes as a beneficial component of personal identity, an internal

process of self-knowledge that is facilitated by running. This fits into the design concept of camouflage, aimed to blur and blend, shifting the focus from illness to identity (Kanstrup, 2014).

Moreover, pursuing a goal such as a marathon can be viewed as unattainable, challenging and absolutely out of reach for most diabetes' patients. There is, in fact, plenty of literature to explain those barriers (Brazeau et al., 2008; Lascar et al., 2014; Finn, 2018; Kennedy et al., 2018). To improve this outlook, the marathon experience from a design perspective allows us to disaggregate the process and helps to identify lessons or recommendations that can be easier or more feasible to apply to a larger T1D audience. Thus, the T1D marathon runner may act as a good example to motivate other people with diabetes to engage in PA.

Conclusion

This paper presents six design insights to understand and raise valuable information for patient self-management around glycemic control in T1D runners, with the potential to be shared with stakeholders to improve their communication, collaborate, and co-create better user-centered diabetes management strategies.

Moreover, self-care and sports goals facilitate and allow for internal and external validation in T1D context: internally because the training process helps to get a deeper understanding of the physical and emotional self; and externally because sports competitions are also social events that can be shared and celebrated with others. Thus, endurance PA can be taken as an empowerment tool to raise self-care efficiently with T1D.

Furthermore, the term "diabetes domestication" is proposed as a positive adaptation process pursued by T1D people and prompted by running. Moreover, glycemic control is confirmed as the main challenge for T1D patients, and it is a key indicator of achievement in the domestication process.

Future studies involving similar design methods with T1D subjects engaged in endurance PA could further examine 'domestication' by testing models for glycemic archetyping, hypo and hyperglycemia, mapping the journey of other sports and evaluating gender differences that were identified in this study.

Design recommendations for diabetes care

Design recommendations highlight the applicability of using design tools to find out more about the changing context within which T1D runners are immersed. Such recommendations are intended to help ensure that outcomes are future-proofed (Chief Medical Officers NHSS, 2017), allowing the patient to take a step back and commit more time to discovery. This is critical for the initial stages of problem-solving and consequently for finding better solutions for diabetes management. In this section, *design recommendations aligned with empowerment-based strategies for diabetes self-management* are proposed for self-care considering each of the six insights listed above. These recommendations are based on the experience in Chile; however, they may also be of use in other countries for runners with chronic illnesses who need real-life experiences and suggestions that they can relate to. They will also be of interest to design researchers and health providers interested in a better connection with patient needs and in developing new strategies for self-management. This is of particular contemporary relevance since the number of endurance runners with T1D has been growing in recent years, according to the global grassroots movement "Type One Run" (Beyond Type One, 2021).

Sharing and learning

In contrast to medical perspectives focused on the individual self-management of health data, the concept of sharing is collaborative and qualitative (Kanstrup et al., 2015). In order to share, the runner first has to understand their own identity as a participant of a group, and the identity map proposed in this study gives the runner the opportunity to define how their character is merged with the T1D and to guide self-introspection, giving them a base to share. Consequently, in this study, instruments used for data collection and data visualization facilitated sharing of both qualitative and quantitative information between T1D runners and health professionals in a collaborative manner (see Insight 1: *Solo learning and shared emotions insight*). This insight is reinforced by the design concept proposed by Kanstrup et al. (2015) of sharing chronic illness, which foregrounds users' active participation, mutual engagement, joint enterprise, and a shared repertoire as a basis for negotiating meaning in practice among participants. From a design view, this could structure what Hakken et al. (2008) call a *community of practice*, a group of people who share a concern and learn how to perform a task more effectively as they regularly interact and build design knowledge.

Introspection for understanding

Design to prepare for discomfort and support individuals and groups to make sense of it (Schraefel et al., 2020) is in accordance with a more hypervigilant T1D runner profile (see insight 2). In this outcome, the patient's view was considered for a better collection of self-observational and self-reflective data through analytic autoethnography, becoming a co-creator and an enhancer of data compilation that was significant for T1D self-management (when intensive PA is involved). Hence, *analytical autoethnography in design* can be recommended to help structure approaches for thinking about a particular aspect of a problem, pushing the understanding and ensuring a broader range of possibilities have been addressed. Furthermore, with the T1D runner – as well as in diabetes healthcare as Inns & Mountains have described (Inns and

Mountain, 2020) – what is often required is working within very complex systems that need careful unpacking before we suggest improvements and change. Thus, the design management perspective aids the integration of information gathered from the running experience – and this avoids data perception as a threat.

Learning from the experience

Chronic illnesses are associated with uncertainty boosting depression and anxiety symptoms (Hoth et al., 2015), a finding which is echoed above in Insight 3. Design management perspectives imply problem-based learning; for diabetes patient education, this provides a tool for uncertainty reduction strategies. Reducing and excising ambiguity is part of a designer's practice. From a pragmatic point of view, design aims to solve problems (Borja de Mozota, 2003) and manage uncertainty. One of the most robust design tools for reducing uncertainty are prototypes or representations of a design idea, which help explore or demonstrate some aspect of the future artifact (Houde and Hill, 1997). The *journey map* is a mode of experience representation built through the iterative training process; it is here recommended as a strategy to reduce uncertainty during PA in T1D (see insight 3). Similarly, Chetty et al. (2019) declare the importance of building a framework for PA accomplishment in young people, including carbohydrate intake, insulin bolus, and exercise time and intensity, all of which can be prompted by *journey map design* as shown in this study to accomplish endurance PA. This design tool encourages patients to apply *problem-based learning* that (according to Funnell et al., 2007) promotes the development of relevant skills to solve self-identified problems in a simulated "real-world" environment, such as conceptual reasoning, empathy for different viewpoints, communication, collaborative working styles, and self-directed learning.

Prototyping for empowerment

To give the patient enough confidence to solve their needs for diabetes management and improve their diabetes empowerment (see insight 4), prototyping as a design recommendation could help test and iterate self-management strategies, adjusting elements integrated in the journey map, such as insulin bolus, carbohydrate intake and glucose levels. As previously stated in Practice Design for Empowerment and Self-Management recommendations (Funnell and Anderson, 2004), prototyping is most effective once providers and their team have defined and expressed a shared vision of diabetes care and education, which can then be used to guide practice redesign (Funnell and Anderson, 2004) in order to adapt it to patient-specific needs. Echoing this idea, Kanstrup et al. (2015) previously demonstrated the impact of prototyping in relation to diabetes in order to co-create solutions and possible actions in a safe way. In addition, prototypes support participants in understanding the dynamics of the elements of the diabetes clinic models for example, a nutritional data prototype that was able to give information from service providers regarding ingredients in unlabeled food.

Ethnography to close gaps between T1D and PA: With available technology, T1D people are more involved in their self-health care and consequently demand more information, putting higher pressure on developing design strategies and on healthcare systems to successfully fill the gap between what patients expect and current healthcare practices (Frascara et al., 2018). Using patients' complex journeys to exercise development (insight 5) as a design tool helps to bridge that gap: this places user experience and empathy at the heart of healthcare improvement projects and innovation, which can then be analyzed and measured by process mapping (Inns and Mountain, 2020), boosting self-observation and T1D self-management t.

In this regard Mamykina et al. (2006), through an ethnographic observational study, use a "culture probe" or activity framework that is useful in understanding the correlation between daily activities and blood sugar levels, suggesting the patient must become a detective of their condition, in order to "proactively engage in the analysis of their disease." Similarly, the outcomes of the present research related to journey map fit with a design ethnography study, including both descriptive and prospective dimensions, which reflect in actions to commit in their T1D understanding for the running practice.

Archetyping glucose profiles

Blood glucose awareness training (Cox et al., 2001; Delamater et al., 2001) is an empirically validated cognitive-behavioral therapeutic intervention that teaches patients to identify their idiosyncratic symptoms of hypo-and hyperglycemia as an adjunct to self-monitoring of blood glucose and has been shown to decrease anxiety in patients with T1D (Groot et al., 2016). Considering glycaemia as a polysemic concept for T1D runners (see insight 6), it would be useful to align glycaemia's objective and subjective/perceptual dimensions. Thus, archetyping could be helpful both for building glycemic profiles that integrate glycaemia perception for runners and for promoting anxiety control around glucose monitoring during exercise execution. Just as patient archetypes evolve, according to O'Connor (2002) it would also be consistent for glycaemia archetypes to change according to PA type, time and intensity, as well as life stages with T1D. For example, one archetype for glycaemia could be determined by the level of interference it has with the activity, because this could force the athlete to conclude or interrupt a competition or training session.

These design recommendations are proposed for use by healthcare providers and patients looking for better diabetes management for runners following the Empowerment and Self-Management recommendations for Design Practice proposed by

TABLE 2 Design recommendation to encourage self-management for T1D runners.

Design recommendation	Self-management strategies
Communities of practice	Involving the group of T1D runners in problem-solving, promoting opportunities for exchange experiences and co-create diabetes management solutions.
Analytical autoethnography	Auto-critic and self-reflexive analysis of their experience boost setting behavioral goals, reinforcing the T1D runner as an expert on their own support needs and making them responsible for daily self-management decisions. This requires a thorough record process of data collection.
Identity mapping	Creating opportunities for self-knowledge and diabetes acceptance, in order to facilitate social and emotional support.
Problem solving	Confirming the ability of T1D runners to identify their own problems and determine an approach to diabetes self-management that will work for them.
Prototyping	Providing information to nurture informed decision making throughout the lifetime of diabetes systematizing the trial-and-error process and boosting patients' decision making.
Experience journey mapping	Integrating and visualizing multiple factors that affect diabetes management for a T1D runner, including clinical, psychosocial, and behavioral aspects which is a complex process.
Archetyping	Respecting the cultural background and beliefs of the T1D runners to connect with their needs.

Funnell et al. (2007) (Table 2). All of the above can make tangible records, visualize, test and better integrate T1D data for decision making, diabetes empowerment and minimizing the barriers that the condition imposes for PA, hoping to enrich physical culture in the T1D population.

Data availability statement

The data that support the findings of this study are available upon request from the corresponding author DM.

Ethics statement

The studies involving human participants were reviewed and approved by Universidad Católica de Chile Ethics Committee (ID 190725002). The participants provided their written informed consent to participate in this study.

Author contributions

DM-B and RS: conceptualization. DM-B, KD-C, RS, and SC-C: formal analysis, writing original draft and writing review and editing. DM-B: funding acquisition, methodology, project administration, resources, and supervision. DM-B, KD-C, and SC-C: validation. DM-B and KD-C: visualization. All authors contributed to the article and approved the submitted version.

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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

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1013877/full#supplementary-material

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Influence of training and selection on postural stability and its relationship with sport level in judo practitioners aged 11–14 years

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The aim of this study is to determine the influence of training and selection on postural stability and its relationship with the sports level of judo practitioners aged 11–14 years. The study group consisted of 21 children judokas, aged 11–12, and 80 of their non-training peers, as well as 19 adolescent judokas, aged 13–14, and 76 of their non-training peers. The judokas were surveyed during regional championships. The level of achievement was determined by the place taken in the tournament. The balance was assessed with the use of a CQ Stab 2P stabilographic platform (CQ Elektronik System, Poland). The device recorded the position of the foot center of pressure (COP) from 6 sensors; 3 of them being located in each platform plate. The following parameters describing the movement of the foot COP were analyzed: total path length calculated in both axes (SP); mean COP inclination (MA), size of the surface area delineated by COP (SA); mean COP frequency (MF). Significantly higher values of SP, MA, and SA were noted in non-training children (aged 11–12), while MF values were significantly higher in young judokas. The same regularity was found in the older age group. Upon comparing the means between children judokas and adolescent judokas, significant differences were noted in the case of SP and MF. In both cases, higher mean values were found in the younger judoka group. A similar comparison in the non-training group indicates statistically significant better values of all analyzed indicators in the 13–14 year-old group, except for MF. Upon examining the relationship between the values of the parameters characterizing the balance level and the sports level, both in the group of training children and adolescents, insignificant values of correlation coefficients were obtained.

KEYWORDS

combat sports, balance, somatosensory science, children and adolescents, postural stability (postural control)

Introduction

Balance, understood as the process of controlling the location of the body's gravity projections in the area of the base area of the body, takes its most complex form in situations requiring resistance to strong destabilizing stimuli (Kioumourtzoglou et al., 1997; Blaszczyk et al., 2000; Paillard and Noe, 2006). Conceptually, it approaches the phenomenon of stability, describing the physiological mechanisms of maintaining and restoring posture that prevent falling. A fall is caused by a person's center of mass (COM) going beyond the stability limit, defined as the optimal position of the foot center of pressure (COP) within the base surface and the size of the safety limit (Blaszczyk et al., 2000; Blaszczyk, 2010). Postural stability is important in everyday situations, but it is in sport that its maintenance requires the most efficient regulatory and control processes (Hrysomallis et al., 2006; Paillard and Noe, 2006). Most studies show a strong positive relationship between physical activity, including sports, and the improvement of balance indicators. Comparisons between training people practicing judo, karate and wrestling, and non-training people, seem to confirm this thesis (Hrysomallis, 2011; Rzepko et al., 2019; Slomka et al., 2019). Nevertheless, the research also shows that such an advantage is not achieved in all conditions of the implementation of balance maintaining task. In the absence of visual control, the authors report a lack of differences between the training and the healthy non-training people (Paillard and Noe, 2006) in terms of balance indices.

Assuming that a smaller range of swaying is synonymous with a higher level of balance in non-training individuals, it should be remembered that this indicator, very often determined by researchers basing on measurement in static conditions, does not reflect the complexity of individual strategies for controlling body stability developed by athletes from various sport disciplines (Blaise Williams et al., 2016). All the more so if the sports activity requires its dynamic form. The authors' opinions indicating that increased swaying while standing calmly is not always synonymous with postural instability, as the control of spontaneous swaying and postural response to balance disturbances are carried out on the basis of various posture control mechanisms (Blaszczyk, 2010). These mechanisms are particularly important in sport disciplines where the goal is to disrupt the opponent's stability and make him/her fall. Judo is such a sport. The essence of stand-up fighting in this discipline is to throw the opponent off balance by leaning (Japanese *kuzushi*) and then by stepping forward and throwing (Japanese *kake*) causing him/her to fall onto the largest possible area of the back. Judo fighting is based on the constant throwing not only the opponent, but also oneself off balance, as it is an indispensable condition for an effective throw. Loss of balance, just like regaining it, are permanent states during a fight, as 70% of the fight takes place in an upright position (Sterkowicz and Franchini, 2000).

Maintaining balance is based on the broad integration of the activities of various human body systems: vestibular, visual, somatosensory, and motor systems (Nashner, 1997). The functions of the sensory systems ensure the control of head movements in space, the movement of individual body segments in relation to each other or contact with external objects (Winter, 1995; Ivanenko and Gurfinkel, 2018). Their hierarchy changes depending on the conditions in which the stability control processes must take place. The reference to this information is due to the fact that what remains unresolved in the case of judokas, is their stability. In different sport disciplines, depending on their specificities, the role of visual, vestibular, or somatosensory information may increase. The authors (Blaise Williams et al., 2016) also suggest that whether the athletes train or compete on a stable or unstable ground will result in the development of specific motor strategies in response to destabilizing factors. In combat sports, and judo in particular, the role of vestibular information is assumed to be important: both from within the lower limbs joints, which seems obvious to maintain balance, but also from the upper limbs and the torso.

Studies conducted using computerized dynamic posturography (CDP) by Leong et al. (2011) show significantly better balance of taekwondo athletes, mainly in static tests with eyes closed. This indicates a significant share of the somatosensory base in combat sports athletes. This type of research makes it possible to assess changes in the structure of balance control, and the fact that the aforementioned work analyzed the results of beginner yet adult athletes suggests that training during the developmental period may bring even greater benefits, overlapping with natural development processes.

The analysis of these natural changes underlying postural stability shows that they occur in different ways depending on the type of motor task. This involves a response based on proprioceptive, vestibular, or visual mechanisms, which changes with individual development. The age of our subjects, compared to younger children, is conducive to the improvement of stability indicators based primarily on somatosensory information and suppression of incorrect visual information. In older age categories, progressive changes concern mainly vestibular-based responses (Steindl et al., 2006).

So far, the inquiries of scientists have focused mainly on the analysis of changes in the level of stability along with the increasing training experience. A less frequently investigated field, however, is the relationship between the level of balance presented by athletes and their sports level, i.e., the research on determining the role of balance and its impact on the sports result. In studies carried out in the groups of cadets (aged 15–16), juniors (aged 16–18), and

seniors (aged over 18) (Lech et al., 2007, 2011, 2014), no correlation was found between the level of balance (assessed using the Flamingo balance test) and the sports level of athletes. When examining contestants aged 16–19, divided into two categories in terms of their sports level, Paillard et al. (2002) did not observe any significant differences between the stability indices under static conditions, indicating only a different sensory organization between the groups. This implies that specific forms of motor control were developed during training that distinguished better athletes from worse athletes.

The novelty of the present is the analysis of the impact of training and selection on balance indices in judo practitioners aged 11–14. No results of analyzes on this subject were found in the available literature. In addition, the relationship between these indicators and the level of achievement in occupations was examined. Also this topic is completely new to this age group.

The authors of the study adopt a working hypothesis that targeted judo training increases the level of stability control, and its level depends on the level of sports achievements.

Materials and methods

Participants

The study group consisted of 21 children judokas aged 11–12 and 80 of their non-training peers, and 19 adolescent judokas aged 13–14 and 76 of their non-training peers. Only healthy individuals without any short-term or long-term injuries were qualified for the study. The judoka tests were carried out during regional championships. They were made on the competition day, after the official weigh-in. The comparative group consisted of students from schools in the Małopolskie province in Poland. They did not participate in any organized physical activity, either now or in the past. The tests in all groups were carried out in a separate room ensuring peace and quiet, the ambient temperature was 22°C; they took place in the morning (10–12) and were conducted by the same research team.

Participation in the research was voluntary. It was carried out in accordance with the Helsinki Declaration. Each subject was informed about the purpose of the research and could withdraw from further participation in the research at any time without giving any reason. The coach, who was the legal guardian of the subject during the competition, and, in the case of the comparison group, the parents and the school principal had to give their consent to the study participation.

Body weight was determined using the Tanita TBF-551 body composition analyzer (Japan) with an accuracy of 0.1 kg. Body height (BH) was measured with an accuracy of 0.1 cm according to Martin's technique, using a set of Swiss devices from SIEBER HEGNER MACHINES SA. The research also used a questionnaire, which included questions about age and training experience. The level of achievement was determined based on the place taken in the tournament. Thus: 1st place–9; 2nd–7; 3rd–5; 5th–3.5; 7th–1.5; 9th–0.5 points. **Tables 1**, **2** show the characteristics of age, training experience, and somatic indicators of the study participants in two age categories.

Study design

The balance was assessed on the CQ Stab 2P stabilographic platform (CQ Elektronik System, Poland). The device recorded the position of the foot COP from 6 sensors, located 3 in each platform plate. Sampling was 200 Hz for each sensor. The platform plates were properly leveled and their surfaces their surfaces were aligned to form a single plane. The study consisted of a 30 s measurement of body stability in a relaxed standing position with eyes open. The width of the lower limb spacing and the angle of the feet opening were natural, unconstrained. Opposite the test subject, a fixation point was placed 1 m away. Once on the platform, the subject stood still and tried to keep his/her gaze on the fixation point. Participants did not perform a warm-up or practice test. The following parameters describing the movement of the foot pressure center (COP) were analyzed:

1. SP (mm) (Sway Path)—the total length of the path in both axes;
2. MA (mm) (mean amplitude)—mean sway of COP (foot pressure center);
3. SA (mm^2) (Sway Area)—size of the surface area delineated by the COP;
4. MF (Hz) (Mean Frequency)—mean frequency of the COP.

The study was approved by Regional Medical Chamber in Kraków, Poland, and granted permission No. 108/KBL/OIL/2014.

Statistical analysis

Multivariate tables were used to characterize the study material. For comparisons of means, the Student's *t*-test for unrelated variables, the Cochran–Cox test and the Mann–Whitney U test were used, depending on the distribution and homogeneity of variance. The homogeneity of variance was checked with Levene's test. The assumption of normality of distributions was verified by the Shapiro–Wilk W test. Spearman's rank correlation coefficient (R) according to the variable type was used in the correlation analysis. A significance level of $p < 0.05$ was adopted in all analyzes. STATISTICA 13.3 software was used for statistical analysis.

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TABLE 1 Age, training experience, and somatic build of study participants in children's group (age 11–12).

	Children judokas					Non-training peers				
	N	Mean	Min.	Max.	*SD*	*N*	Mean	Min.	Max.	*SD*
Age (years)	21	11.4	11.0	12.0	0.5	80	11.6	11.0	12.0	0.5
Height (cm)	21	149.3	141.0	164.0	5.8	80	154.7	141.0	177.0	8.0
Body mass (kg)	21	40.6	30.3	47.8	5.4	80	48.0	28.9	90.1	12.2
Training experience (years)	21	4.3	3.0	7.0	1.7	0				
Level of achievement (points)	21	3.9	0.0	9.0	3.0	0				

TABLE 2 Age, experience, and somatic build of study participants in the group of adolescents (13–14 years old).

	Adolescent judokas					Non-training peers				
	N	Mean	Min.	Max.	*SD*	*N*	Mean	Min.	Max.	*SD*
Age (years)	18	13.4	13.0	14.0	0.5	76	13.3	13.0	14.0	0.5
Height (cm)	18	163.6	149.0	176.5	6.9	76	162.7	139.0	182.0	8.83
Body mass (kg)	18	54.8	43.1	74.7	8.3	76	53.8	30.8	95.1	13.1
Training experience (years)	18	5.8	4.0	8.0	1.3	0				
Level of achievement (points)	18	2.8	0.0	9.0	3.1	0				

Results

Table 3 summarizes the values of the parameters characterizing the level of balance in judo children (11–12 years old) and their non-training peers. When comparing the mean values between the studied groups, statistically significant differences were obtained in all cases. For SP (mm), MA (mm), and SA (mm^2), higher mean values were recorded in the non-training, respectively: 343.09, 2.71, and 303.16. In judo athletes, these averages were respectively, 313.10, 1.23, and 113.43. In the MF (Hz) range, judokas had a higher mean frequency of corrective reactions (1.69, in non-trainers: 0.77).

In the older age group, significant intergroup differences were noted for all analyzed indicators (Table 4). In the case of SP (mm), MA (mm), and SA (mm^2), higher averages were recorded for those who did not train, and in the case of MF (Hz), a higher average was recorded for judo competitors.

Comparing the means between children judokas and adolescent judokas, significant differences were noted in the case of SP (mm) and MF (Hz). In both cases, higher mean values were observed in children, 331.10 and 1.60, respectively. In the group of youngsters, the mean SP (mm) was 257.83 and MF (Hz) was 1.07 (Table 5).

A similar comparison in the group of non-training persons indicates statistically significant better values of all analyzed indicators in the group of adolescents (Table 6), with the exception of the frequency of MF (Hz) correction reactions.

When examining the relationship between the values of the parameters characterizing the balance level and the sports level, both in the group of children and adolescents, insignificant values of correlation coefficients were obtained (Tables 7, 8).

Discussion

The aim of this study was to analyze the impact of training and selection on balance indices in judo practitioners aged 11–14, and to determine their relationship with the level of performance in competitions.

The results obtained during the study indicate a positive influence of the trained discipline on the static balance indicators. Both in younger and older groups of judokas, a higher level of balance control mechanisms was found than in their non-training peers. The author's own data are confirmed by numerous studies in which the authors note the positive effect of combat sports on improving the functioning of the vestibular organ, especially deep feeling, which in judo plays a major role in stability control (Lemoth et al., 2009; Fong et al., 2011; Truszczyńska et al., 2015; Maśliński et al., 2017). In the case of combat sports practitioners, where a significant part of the competition requires, for example, maintaining the balance in a one-legged position (similar to, e.g., dancers or skaters), the advantage over the non-training individuals is observed in all conditions of the balance task (static and dynamic), unilateral and bilateral (Hahn et al., 1999; Perrin et al., 2002; Matsuda et al., 2008). As one may also find data that do not confirm the occurrence of such relationships (Witkowski et al., 2014), a few remarks should be made: firstly, not all physical activity improves

TABLE 3 Values of parameters characterizing the level of balance in children judokas (11–12 years old) and their non-training peers.

Children judokas						Non-training peers					Test result	*p**
	N	Mean	Min.	Max.	*SD*	*N*	Mean	Min.	Max.	*SD*		
SP (mm)	21	313.10	251.00	385.00	38.05	80	343.09	198.00	599.00	81.34	C-C = −2.44	0.017
MA (mm)	21	1.23	0.50	3.20	0.61	80	2.71	0.80	5.60	1.09	*U* = −5.82	0.000
SA (mm^2)	21	113.43	36.00	305.00	61.24	80	303.16	75.00	746.00	152.25	*U* = −5.88	0.000
MF (Hz)	21	1.60	0.60	2.91	0.61	80	0.77	0.30	1.75	0.31	*U* = 5.49	0.000

**p*–significance level; C-C, value of the Cochran–Cox test; *U*–value of the Mann–Whitney U test.

TABLE 4 Values of parameters characterizing the level of balance of adolescents (13–14 years old) practicing judo and their non-training peers.

Adolescent judokas						Non-training peers					Test result	*p*
	N	Mean	Min.	Max.	*SD*	*N*	Mean	Min.	Max.	*SD*		
SP (mm)	18	257.83	190.00	326.00	42.54	76	312.71	166.00	470.00	75.93	CC = −4.1	0.000
MA (mm)	18	1.62	0.60	3.50	0.88	76	2.23	0.90	5.50	0.84	*U* = −2.9	0.003
SA (mm^2)	18	118.50	34.00	240.00	69.10	76	230.79	69.00	594.00	114.62	U = −4.2	0.000
MF (Hz)	18	1.07	0.48	2.11	0.51	76	0.82	0.35	1.56	0.27	CC = 2.1	0.049

C-C, value of the Cochran-Cox test; *U*–value of the Mann–Whitney U test.

TABLE 5 Values of parameters characterizing the level of balance in children and adolescent judokas.

Children judokas						Adolescent judokas					Test result	*p*
	N	Mean	Min.	Max.	*SD*	*N*	Mean	Min.	Max.	*SD*		
SP (mm)	21	313.10	251.00	385.00	38.05	18	257.83	190.00	326.00	42.54	*t* = 4.28	0.000
MA (mm)	21	1.23	0.50	3.20	0.61	18	1.62	0.60	3.50	0.88	*U* = −1.35	0.176
SA (mm^2)	21	113.43	36.00	305.00	61.24	18	118.50	34.00	240.00	69.10	*U* = 0.03	0.978
MF (Hz)	21	1.60	0.60	2.91	0.61	18	1.07	0.48	2.11	0.51	*t* = 2.89	0.006

t, Student's *t*-test value for unrelated variables; *U*–value of the Mann–Whitney U test.

TABLE 6 Values of parameters characterizing the level of balance in children and adolescents.

Children						Adolescents					Test result	*p*
	N	Mean	Min.	Max.	*SD*	*N*	Mean	Min.	Max.	SD		
SP (mm)	80	343.09	198.00	599.00	81.34	76	312.71	166.00	470.00	75.93	*t* = −2.4	0.017
MA (mm)	80	2.71	0.80	5.60	1.09	76	2.23	0.90	5.50	0.84	*U* = −2.9	0.004
SA (mm^2)	80	303.16	75.00	746.00	152.25	76	230.79	69.00	594.00	114.62	*U* = 3.0	0.003
MF (Hz)	80	0.77	0.30	1.75	0.31	76	0.82	0.35	1.56	0.27	*U* = −1.3	0.180

t, Student's *t*-test value for unrelated variables; *U*–value of the Mann–Whitney U test.

stability control mechanisms to the same extent; secondly, externalization of their efficiency may require certain conditions (static or dynamic); and thirdly, and finally, not all traditional methods of assessing balance, especially in static, are adequate for assessing its mechanisms in athletes.

The influence of the sports level on the stability of judokas is not explicitly assessed positively in the publications. There are studies in which the authors find no differences in the static balance indicators between athletes of various sports levels (Maśliński et al., 2015, 2016). At the same time, they notice significant differences between them in terms of dynamic balance. The reason for this may be the fact that judo training alters the hierarchy of receptor inputs used in balance control in favor of the increasing role of visual and vestibular information in elite athletes (Witkowski et al., 2004). A comparison of athletes at different stages of sports specialization shows that not always lower values of stability indicators represent its higher level (Witkowski et al., 2021). Based on the research, the authors note that athletes, under the influence of training (which is an expression of specific motor adaptations to

TABLE 7 Values of rank correlation coefficient calculated between the parameters characterizing the level of balance and the level of achievement in competitions in the group of children.

Correlated parameters	*N*	*R*	*t*(*N*-2)	*p*
Level of achievement and SP	21	−0.099	−0.434	0.669
Level of achievement and MA	21	0.113	0.494	0.627
Level of achievement and SA	21	0.093	0.408	0.688
Level of achievement and MF	21	−0.180	−0.798	0.435

TABLE 8 Values of the rank correlation coefficient calculated between the parameters characterizing the level of balance and the level of achievement in competitions in the group of adolescents.

Correlated parameters	*N*	*R*	*t*(*N*-2)	*p*
Level of achievement and SP	18	0.296	1.241	0.232
Level of achievement and MA	18	0.174	0.708	0.489
Level of achievement and SA	18	0.278	1.158	0.264
Level of achievement and MF	18	−0.174	−0.705	0.491

specific tasks) acquire and train specific motor strategies. Therefore, they caution against the automatic unfavorable interpretation of the increased indexes of the displacement range of COP and the surface area SA. Our study fully supports this thesis, as lower values of the SP path length in older judokas are accompanied by a higher amplitude of corrective reactions (MA). This is justified by the increased sensitivity thresholds of sensory systems, which results in a delayed response increasing the economy of corrective reactions (Blaszczyk et al., 1993; Cieśliński et al., 2016, 2017; Witkowski et al., 2018). This is in line with the reduced frequency of these reactions (MF) discussed later. The increased swaying range observed in qualified judokas compared to beginners may therefore be a sign of increased adaptation. It is also significant to compare the differences in the frequency of corrective reactions between the non-trainers and judokas. In the former, an increase in frequency can be seen, which, in the light of the literature, indicates a lower economy of maintaining the balance. According to the authors, this applies to both free standing and more demanding positions (maximum lean, one-legged standing, etc.). The authors observe an increase in frequency alongside with the complication of a motor task (Kuczyński, 2000), therefore its lower values in qualified athletes are a direct evidence of more efficient performance of postural tasks.

The lack of correlation between the sports level indicators and balance indicators suggests the existence of more important components influencing the sport performance than a high level of balance. The lack of a relationship between the balance ability and the sports level of judokas was also noted by Hrysomallis (2011), indicating that balance training may be a factor in aiding athlete development by creating better conditions for mastering technical skills.

The conducted study has some limitations resulting primarily from the adopted methodology and the instrumentation used. Measuring balance in static conditions may not fully reveal differences between training and non-training individuals. Being a cross-sectional one, our study lacks the strength of the experiment, so we can only assume that the differences found are mainly the effect of post-training changes. It also seems that the natural direction of further work should be to determine changes in dynamic stability under the influence of controllable experimental stimuli.

Conclusion

The analysis of the obtained results shows that in each category the trainers dominate over the non-trainers. This is a clear confirmation that practicing judo supports the natural processes of the development of postural stability by enhancing their effect.

Bearing in mind the limitations presented in the discussion section, it should be stated that in all the examined age categories, the training individuals are characterized by a higher level of stability. This trend overlaps with the natural process of improving stability indicators, also confirmed in the study. However, the hypothesis assuming a relationship between stability and sports level was not confirmed. In this case, it seems that it may be due to the wide range of the presented level, which, given the relatively small numbers, did not allow to capture any possible relationships. On the other hand, additional research would perhaps make it possible to determine whether the improvement of the competitive level of judokas from a certain level on depends to a greater extent on other elements than stability.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the Regional Medical Chamber in Kraków, Poland, No. 108/KBL/OIL/2014. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

JJ and GL contributed to the conception and design of the study. JJ, GL, PB, and KS organized the database and performed the statistical analysis. JJ, GL, KW, PB, KS, and PP wrote the first draft of the manuscript. GL and PP wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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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.

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Examining the validity of the polish short form version of the self-regulated learning—sport practice survey among competitive athletes

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Introduction: Self-regulated learning entails psychological processes that elite athletes employ to optimize their practice. Although self-regulated learning provides insights into athlete-led practice, research has been limited to few cultures, and the particularities of how SRL surveys perform in new cultural contexts require attention. Moreover, there exists no measure to assess SRL and its relationship to quality sport practice in Polish. Thus, we examined the Short Form of the Self-Regulated Learning—Sport Practice survey in Polish. Analyses addressed the factorial validity and reliability, the criterion validity (by assessing differences in scores between competition levels), and the concurrent validity (by correlating scores with conceptually related constructs) of a Polish Short Form survey.

Methods: Athletes (N=324, M_{age}=21.4, $n_{females}$=144, n_{males}=180) from amateur, regional, national, and international-elite levels completed the survey, along with concurrent subscales (General Self-Efficacy Scale; GSES; Metacognitive-Self Scale; MS-24; Action Control Scale; ACS-90).

Results: Confirmatory factor analysis indicated a two-factor (metacognitive; motivational) model (RMSEA=0.082, SRMR=0.057, CFI=0.89). Between-group tests showed international-elite scoring higher than all other groups on metacognitive and motivational subscales. On both subscales, significant trends indicated that more skilled levels consistently reported higher scores than lesser-skilled levels. The short form scores were associated with certain concurrent variables, including GSES (r_{meta}=0.41, r_{motiv}=0.48), MS-24 (r_{meta}=0.39, $r_{motiv=0}$.24), and ACS-90 (AOF subscale: $r_{motiv=0}$.26).

Discussion: On the basis of strong criterion validity, and moderate evidence for concurrent validity, we conclude that the Polish Short Form of the Self-Regulated Learning—Sport Practice survey is a promising tool for use in Polish sport and we discuss future avenues of work to enhance its validation. Limitations that inform future research include our reliance on a mixed-sport sample, the lack of priming of obstacles/challenge ahead of self-report, and a lack of consideration of sport-specific practice variables in analyses.

KEYWORDS

self-regulation, sports level, expertise, self-assessment, metacognition, motivation regulation

Introduction

Self-regulated learning (SRL) has received a lot of recent attention in the sport context (Toering et al., 2012a; McCardle et al., 2018; Wilson et al., 2021). Evidence suggests that SRL, which comprises active, self-directive psychological processes, is useful for improving practice activities because it can help learners to self-monitor, regulate, and control cognition, motivation, affect, behavior, and aspects of the environment to achieve learning goals (Kolovelonis et al., 2012). SRL competencies are related to effective sport practice and to the achievement of higher skill levels (Anshel and Porter, 1996; Bartulovic et al., 2017), which suggests that self-regulated athletes get more out of their athletic potential (McCardle et al., 2017). An instrument that effectively measures SRL may help to identify athletes' strengths and weaknesses with respect to optimal psychological engagement in practice activity (Young et al., in press).

Self-regulated learning research across different sport cultures

Self-report measures of SRL have been investigated in a limited selection of cultural contexts. Toering et al. (2012a), based in the Netherlands, created the first self-report survey for SRL in sport by combining existing scales from education research in English. They translated the survey to Dutch and assessed factorial validity for their 48-item, six subscale model in a sample of Dutch youth academy soccer players, advancing four metacognitive subscales: "planning," "self-monitoring," "self-reflection," and "self-evaluation," and two motivational subscales: "effort" and "self-efficacy." Subsequent studies found that higher-performing Dutch adolescent athletes scored higher than less-elite counterparts across multiple sports (e.g., Jonker et al., 2010), and more specifically, that SRL scores were related to ball control development among basketball players (te Wierike et al., 2018).

English versions of Toering et al. (2012a) survey have been extensively examined and updated for use in a North American (primarily Canadian) context. Bartulovic et al. (2017) worked with domain experts to adapt the survey to the context of sport practice and found that their survey effectively discriminated between three performance levels in a mixed-sport sample. McCardle et al. (2018) sought to reinforce the conceptual and psychometric validity of Bartulovic et al.'s survey through extensive psychometric analyses to refine and validate an expanded inventory of items. Their work resulted in 26 items in the Self-Regulated Learning for Sport Practice (SRL-SP) survey. Their five-subscale solution differed from Toering et al. (2012a) six-factor one by integrating self-reflection and self-evaluation, changing "self-monitoring" to "checking," and noting that self-efficacy was assessed in relation to challenges. Recently, Wilson et al. (2021) replicated the five-subscale structure and its factorial validity in another sample of North American athletes. They also found that criterion validity (i.e., differences between four skill-level groups) was retained after controlling for the athletes' biases toward social desirability.

Other investigators have adapted versions of the preceding surveys to new cultural contexts. Pitkethly and Lau (2016) translated the Toering et al. (2012a) survey to Chinese and validated a model with 32 items on six adjusted subscales among two samples of adolescent (non-athlete) Hong Kong students. Ikudome et al. (2017) translated the survey to Japanese, and validated a five-subscale, 37-item solution among university students within school sport clubs. Reverberi et al. (2021) translated Bartulovic et al. (2017) survey to Italian, finding a five-subscale solution (31 items) that showed measurement invariance between male professional and semi-professional footballers in Italy. Peer-reviewed self-report measures of SRL now exist in North American (English), European (Dutch, Italian), and East Asian (Chinese, Japanese) contexts.

Each time an SRL survey has been translated to a new language and/or cultural context has necessitated a slight adjustment to the survey factor structure (5–6 factors) and item selection (26–48 items). Some changes are attributable to minor linguistic modifications. For instance, Bartulovic et al. (2017) changed the word "problem," representing the school-related origin of the scale, to "task" to better represent sport practice. Pitkethly and Lau (2016) used "work" instead because it was more easily understood in translation to Chinese. They also noted that cultural differences in motivational beliefs may affect inter-scale correlations, such as whether effort is invested more for personal gain (i.e., as in more individualist societies) or for the benefit of the group (i.e., more collectivist societies). Although SRL assessment has gained popularity in different countries, it is not known whether the construct is received similarly by respondents, and whether it performs equally in terms of criterion validity, in different cultures. Thus, the current investigation explored the performance of an SRL survey tool in a new cultural context—among Polish competitive athletes.

Despite the various self-report SRL tools, the shortest validated surveys have used 26 to 31 items, which may be too long for use in applied sport consultation settings (Horvath and Röthlin, 2018). In response, Wilson et al. (2019) developed a Short Form of the SRL-SP through secondary analysis of McCardle et al. (2018). A panel of five researchers holding different areas of SRL expertise (e.g., applied consulting, psychometric, theoretical) re-appraised McCardle et al.'s inventory of items and selected 14 for inclusion based on a combination of conceptual and practical merit. Exploratory factor analysis of 482 North American athletes ($Mage = 26.45$, $SD = 12.66$) indicated a two-factor solution—motivation and metacognition subscales—and skill group comparisons among athletes (> 17 years of age), indicating that international athletes scored correspondingly higher than national and provincial athletes on both subscales. Although Wilson et al. presented their Short Form SRL-SP as a viable tool for assessing self-regulated sport practice in applied North American settings with English-speaking athletes, it has yet to be examined in alternative cultural contexts. The current investigation sought to examine this Short Form SRL-SP among Polish athletes.

Criterion validity based on between-group comparisons

Sport expertise researchers have contended that a survey should establish criterion validity by discriminating between multiple, escalating skill groups in a corresponding manner (i.e., higher scores represent higher skill levels) with noted effect sizes (Tedesqui et al., 2018; Wilson et al., 2021). For example, researchers have consistently demonstrated that higher-performing football (soccer) players in the Dutch youth football academy system score higher than their non-elite peers on the SRL subscale of "self-reflection" (Toering et al., 2009, 2012b; Jonker et al., 2010, 2012). Bartulovic et al. (2017) found that subscales of "planning," "self-monitoring," "effort," and "self-efficacy" each predicted membership in the elite group of a North American mixed-sport sample, as compared to less-elite and recreationally competitive

groups, but that only "self-monitoring" did so when considered simultaneously with all other subscale scores. McCardle et al. (2018) and Wilson et al. (2021) both found that international-level athletes from a North American mixed-sport sample scored significantly higher than lesser-skilled athletes on processes of "evaluation/reflection" and "effort." McCardle et al. also found significant differences for "self-efficacy for challenge," although Wilson et al.'s findings also implicated more subscales attesting to criterion validity than McCardle et al. (2018) as trends relating to "planning, "checking," and 'self-efficacy for challenge' subscale scores all pointed to an expert advantage. Finally, Reverberi et al. (2021) found that professional Italian male football players consistently scored higher than semi-professional players across all five subscales. They found small between-group differences for "planning," "self-reflection," and "self-efficacy" scores, medium differences for their "self-supervision" factor, and strong differences on the 'effort' factor.

When researchers neglect to examine inter-group skill differences (e.g., Pitkethly and Lau, 2016; Ikudome et al., 2017), this curtails research practitioners from fully interpreting the validity of the instrument. Although each survey that tested inter-group differences did demonstrate criterion validity, the varying importance of different subscales (e.g., "self-reflection," "effort") between samples suggests that cultural differences in how SRL processes are perceived.

Concurrent validity

Despite extensive investigation of various SRL surveys, little work has assessed how the results of these measures correspond to those of similar constructs (*cf.*, Elferink-Gemser et al., 2015). SRL embraces motivational self-processes (e.g., self-efficacy) and metacognitive capabilities (e.g., planning and self-monitoring) focused on practice-enhancement. Many of these elements can be similarly measured using corresponding single-dimension (e.g., General Self-Efficacy Scale, Schwarzer et al., 2009; Metacognitive-Self Scale, Brycz and Konarski, 2016) or multidimensional scales (e.g., Action Control Scale, Kuhl, 1994a; Marszał-Wiśniewska, 2002). Although these corresponding measures are more general than sport-specific, they have been used in athlete research, in Polish (e.g., Marszał-Wiśniewska, 1998; Blecharz et al., 2014; Wilczynska et al., 2014; Serafin, 2021; Rogowska et al., 2022) and other populations (e.g., Raab and Johnson, 2004). Self-efficacy, for example, is critical to self-regulation and is understood as modulating one's behavior to achieve goals (Rogowska et al., 2022). Basketball experts report higher self-efficacy than non-experts and novices in a practice environment demanding SRL (Cleary and Zimmermann, 2001).

There are parallels between SRL and facets of the metacognitive self. For example, Serafin (2021) reported that kickboxers achieved metacognitive self (MCS) levels above the average for the general population, suggesting they possess well-developed insight regarding their own evaluative biases in action, can accurately predict their own behavior, and have capabilities that allow for conscious correction of mistakes. Research has shown that high MCS fosters self-regulatory functions such as persistence in the face of challenge and focus on non-conflicting goals (Fanslau and Brycz, 2019). Moreover, high-MCS individuals accept uncontrollability more than low-MCS ones (Brycz et al., 2014).

According to action-control theory, volitional capacities are required to translate goals into behavior and are essential for the initiation of action and monitoring goal-relevant behavior in the face of obstacles (Kuhl, 1994b). With respect to such self-regulation, Kuhl (1994a, 1994b) specified that people have either state- or action-oriented mechanisms. Action-oriented people are characterized by mobilization, high activity, and high efficiency of the internal mechanisms of self-regulation, so they can efficiently formulate an action plan as well as take such an action. State-oriented people have problems with planning and initiating activities, and ruminating on setbacks. Research on basketball players showed that state-oriented players regulate poorly and have weaker sporting achievements (Marszał-Wiśniewska, 1998). In light of the aforementioned parallels between SRL and related constructs, one would expect concurrent validity in a Polish athletic cohort to be reflected in associations between SRL scores and higher general self-efficacy, higher MCS scores, and action-control mechanisms.

Research purposes

Although the catalog of SRL surveys is being used more widely, research practitioners cannot assume any one of them, including the Short Form SRL-SP, validly applies across cultures without understanding its validity within a specific cultural context. Validity in a sport performance context should be established through the intersection of multiple considerations, including factorial, criterion, and concurrent validity. As such, this investigation specifically examined the Polish version of the Short Form SRL-SP survey's psychometric characteristics and its constituent themes in a Polish sample, tested the criterion validity of the survey scores *via* inter-group assessment of Polish athletes of different sport levels, and examined its concurrent validity in relation to parallel scores for general self-efficacy, metacognitive self, and action control.

Methods

Participants

Participants were recruited *via* organizational and coach contacts at sports university, clubs, and institutions, and were approached onsite at events or practices around Poland (mainly in Lesser Poland). Participants had to be 18 years of age or older, and actively practicing for and competing in organized sport at either amateur, regional, national, or international-elite levels. We recruited 324 Polish athletes ($M_{age} = 21.4$, $n_{females} = 144$, $n_{males} = 180$) from diverse sports (individual, $n = 161$, and team sports, $n = 163$). To improve the validity of skill grouping (Tedesqui et al., 2018), sport levels were determined based on three questions in a demographic survey. The first asked for the official sport-level classification (i.e., international master class, master class, first, second, third class, etc.) used by particular Polish sport associations. The rules for assigning sport class are based on official state regulations, and a sports class is valid for a maximum of 2 years. The second question asked athletes to report their competitive level (i.e., amateur; regional, national, elite), and the third requested the athlete's greatest achievement in their sport. Based on these multiple criteria, we classified respondents into four escalating sports levels: amateur, $n = 55$; regional, $n = 116$; national, selected to represent Poland, $n = 117$; international elite, $n = 36$.

Procedures

The research was carried out in accordance with the Helsinki Declaration and ethics procedures that received approval from an

academic institution. During an introductory meeting, participants were introduced to the idea of the study and ethical considerations, including informed consent. Surveys were disseminated either in group or in individual sessions, with completion taking about 35 min. Participants completed a demographic survey and Polish versions of the Short Form SRL-SP survey (back-translated from Wilson et al., 2019), the General Self-Efficacy Scale (GSES; Schwarzer et al., 2009), the Metacognitive-Self Scale (MCS-24; Brycz and Konarski, 2016), and the Action Control Scale (ACS-90; Kuhl, 1994a). The latter three surveys already existed in Polish.

Measures

Polish short form SRL-SP

The English Short Form SRL-SP consists of 14 items that assess an athlete's use of metacognitive (10 items; $\alpha = 0.87$) and motivational (four items; $\alpha = 0.73$) self-regulated learning processes (Wilson et al., 2019). All items are assessed on a 7-point scale, where metacognitive items are anchored at each point from 'never' to 'always', and motivational items are anchored at each point from 'strongly disagree' to 'strongly agree' (see Appendix I). Permission to translate and use the Short Form SRL-SP was obtained from the original authors (Wilson et al., 2019). First, a native Polish speaker and certified sport psychologist translated this survey into Polish. Then, a professional translator who was not familiar with the SRL content performed a back-translation. Two discrepancies (items 2 and 6) between the two versions were found. After a discussion with the original authors, corrections were made. This version of the Short Form was next verified with a certified sport psychology practitioner to ensure it was faithful to the scope and the language of Polish athletes; only two words in the survey preface were replaced (Appendix I).

General self-efficacy scale

The GSES (Schwarzer et al., 2009) is a 10-item instrument that explicitly refers to the belief that one's regulatory actions are responsible for successful outcomes (e.g., "I can always manage to solve difficult problems if I try hard enough"). All items are assessed on a 4-point scale anchored at 1—"Not at all true" and 4—"Exactly true." Higher scores indicate a stronger self-efficacy belief. The internal consistency (Cronbach's α) of the GSES ranges from 0.85 to 0.90 in Polish athletic samples (Łuszczyńska et al., 2005; Juczyński, 2009).

Metacognitive-self scale

The MCS-24 (Brycz and Konarski, 2016) is a 24-item scale that assesses knowledge about one's own adaptive biases and about the influence of psychological phenomena on one's own behavior (e.g., "I remember information better when I can relate it to the knowledge I already have"). Participants are asked to rate their agreement with each item on a scale anchored at 1—'Definitely NO' and 6—'Definitely YES' (Brycz and Konarski, 2016). Higher scores indicate a better understanding of how psychological mechanisms and metacognitive biases influence oneself, and better support for self-regulatory functions for behaviors in different areas of life activities (including sport). In a Polish sample, Brycz and Konarski (2016) reported that the discrimination parameters for all test items were statistically significant, ranging from 0.42 to 0.96, and internal consistency values were $\alpha = 0.81$ and $\omega = 0.85$.

Action control scale

The ACS-90 (Kuhl, 1994a; Marszał-Wiśniewska, 2002). assesses volitional capacities and mechanisms that facilitate (or impede) the enactment of intentions. This 36-item measure consists of a series of items that require respondents to choose between two alternatives. For example, after being prompted with "When I know I must finish something soon," they choose: (a) "I have to push myself to get started" (i.e., hesitation orientation) or (b) "I find it easy to get it over and done with" (decision-related action orientation). Following "When I have to carry out an important but unpleasant task," they choose: (a) "I do it and get it over with" (i.e., action orientation) or (b) "It can take a while before I can bring myself to do it" (state orientation; Kuhl, 1994a; Marszał-Wiśniewska, 2002). Action-oriented choices are coded as 1 and state-oriented choices as 0, and these are summed, for 12 items on each of three subscales. The three subscales are: (i) action orientation subsequent to failure vs. preoccupation (AOF); (ii) prospective and decision-related action orientation vs. hesitation (AOD); and (iii) action orientation during (successful) performance of activities (intrinsic orientation) vs. volatility (AOP). The subscales were treated and summed separately. Each of the resulting subscale scores was analyzed as continuous variables, with higher scores representing more action orientation.

Planned analyses

We initially assessed for missing values. Three MCS-24 items contained one missing value representing <0.62% of data. These values were missing at random and were thus replaced using randomly generated values within the range of pertinent scales. We conducted confirmatory factor analysis (CFA), using obliminal rotation[1] and maximal likelihood estimation, to evaluate the factorial structure and internal consistency of scores from the Polish Short Form SRL-SP. We performed as per the English version (Wilson et al., 2019), two CFAs, one for a global factor and a separate analysis for the two-factor model. Multiple criteria were used to assess fit, including root mean square error of approximation (RMSEA) < 0.05, standardized root-mean-square residual (SRMR) < 0.08, comparative fit index (CFI) > 0.90, and Tucker-Lewis Index (TLI) > 0.90 (Kenny, 2020). We assessed subscale reliability with Cronbach's α, with values >0.70 considered acceptable (Nunnally, 1970). Additionally, we reported Average Variance Extracted analysis (AVE).

In terms of criterion validity, we assessed differences between the four competitive levels (amateur, regional, national, and international elite) using Kruskal-Wallis ANOVA and *post-hoc* Dunn tests. Effect sizes for ANOVAs were based on partial eta-squared values interpreted as 0.01 small, 0.06 medium, and 0.14 large. Effect sizes for *post-hoc* comparisons were based on *d* values interpreted as.2 small, 0.5 medium, and.8 large (Cohen, 1988). Preliminary analyses assessed differences in SRL scores between genders. In terms of concurrent validity, after performing Shapiro–Wilk analyses for normality, we conducted Spearman's rho correlations between each of the motivational and metacognitive Short Form SRL-SP subscale scores and the other notable self-regulation related variables (i.e., GSES, $n = 291$; MCS-24, $n = 323$,

1 Obliminal rotation was used due to the strong correlation between factors 1 and 2 ($r = 0.68$).

and the three scales of action control, $n = 198$[2]). All analyses were performed using JASP 0.16 software, with the significance level set at $\alpha < 0.05$.

Results

Factorial validity and internal consistency reliability

The CFA on the global factor model showed the following fit indexes: RMSEA = 0.100 (CI 0.089–0.111), SRMR = 0.072, CFI = 0.829, and TLI = 0.798. The CFA for the two-factor model showed better fit. The items on the two factors matched the English Short Form SRL-SP (Wilson et al., 2019) exactly: 'metacognitive' (10 items, factor loadings 0.52–0.66) and 'motivational' (4 items, factor loadings.64–0.70) subscales, which were correlated at $r = 0.68$ (see Table 1). The two-factor model fit the data as follows: RMSEA = 0.082 (CI.070–0.093) SRMR = 0.057, CFI = 0.887, and TLI = 0.869. Standardized loading estimates should be 0.5 or higher, and ideally.7 or higher (Hair et al., 2019). In our study, Cronbach's α for the metacognitive and motivational subscales were 0.85 and 0.77, respectively. In light of these results, and considering the two-factor model allows for more nuance in facets of SRL, we elected to use the metacognitive and motivational scores in our subsequent analyses.

Criterion validity

Preliminary analyses indicated scores between female and male athletes did not differ ($p_{meta} = 0.06$; $p_{motiv} = 0.58$). A one-way Kruskal-Wallis ANOVA for metacognitive scores was significant, H ($n = 3$, 324) = 15.58, $p = 0.001$, partial eta-square = 0.05. Dunn tests showed significant differences between all of the levels with one exception—the regional athletes' levels were not different from than amateurs (see Table 2). A one-way Kruskal-Wallis ANOVA for motivational scores was significant, H ($n = 3$, 324) = 23.22, $p < 0.001$, partial eta-square = 0.07. *Post-hoc* tests showed significant differences between all of the levels with one exception—the national group was not different from the regional group (see Table 2). Notably, inspection of descriptive statistics indicated "complete correspondence" (Tedesqui et al., 2018, p: 7), that is, with each increasing sport competition level, there was higher report of metacognitive and motivational scores.

Concurrent validity

Table 3 shows the correlation matrix. Short Form SRL-SP motivational scores were significantly correlated with GSES ($r = 0.48$), MCS-24 ($r = 0.25$), and the AOF subscale of action control ($r = 0.26$). Short Form SRL-SP metacognitive scores were significantly correlated with GSES ($r = 0.41$) and MCS-24 ($r = 0.40$) scores.

2 Recruitment was disrupted by COVID restrictions, which limited access to participants and the time they were available. As such, it was not always possible to use all three measures of concurrent validity.

Discussion

The study examined how the Polish version of the Short Form SRL-SP performed according to multiple facets of validity. The Polish short form demonstrated better factorial validity for a two-factor model, comprising a motivational and metacognitive subscale, than a global factor. Based on our sample, the Polish Short Form better lends itself to assessment with two factors, and explains greater variance and fit in the modeled data, which is consistent with what Wilson et al. (2019) also reported in the English version in a sample of competitive North American athletes. The two-subscale solution also offers nuance between the two dimensions of SRL, which is a merit compared to the single scale. The one caveat is that the fit indices in the Polish sample fell just short of established criteria for determining acceptable fit, meaning we would advocate some caution in advocating it as an assessment instrument, especially the global factor. As is evident in this investigation, and indicated by Wilson et al., it was never the intention for the Short Form to be advanced solely as an assessment instrument, and thus, the fit indices might be sufficient when considering other merits of this survey. The internal consistency reliability of the Polish Short Form was strong (0.85 for metacognitive, 0.77 for motivational) and in line with the high values for the English version (0.87 for metacognitive, 0.73 for motivational) reported by Wilson and colleagues.

There was strong evidence of group discrimination attesting to the criterion validity of the Polish Short Form SRL-SP. Scores from the metacognitive and the motivational scales differed significantly between each and every competitive sport level, with the only exception for the two least skilled groups on metacognitive scores. The ANOVA analyses indicated that the omnibus group differences were of a medium effect size for motivational scores, and a small effect (just short of medium) for metacognitive scores. Effect sizes from the *post hoc* tests offered evidence of the experts' advantage. For instance, the international-elite group showed large and medium effects in comparisons to the amateur and regional groups, respectively. The international-elite group also reported small effect size advantages on both subscales over the national group. Moreover, there were generally small to medium effect size differences between all groups across the competitive group simplex. These results are arguably the strongest to date in terms of skill group discrimination (criterion validity) using SRL surveys for several reasons. First, most studies have used two (e.g., Toering et al., 2009, 2012b; Jonker et al., 2010; Reverberi et al., 2021) or three groups (e.g., Bartulovic et al., 2017) for comparative purposes, and four escalating groups provides a more rigorous test (Tedesqui et al., 2018). Secondly, the present trends did not show non-significant anomalies between the least and most skilled groups as was the case in recent work with the full version of the SRL-SP (McCardle et al., 2018). Overall, the effect sizes were somewhat larger and more consistent across more group comparisons than prior research using SRL surveys with three or more skill groups. These findings are a robust example of complete correspondence, with statistical significance at each escalating skill step, suggesting that both metacognitive and motivational SRL competencies contribute to superior sport performance among Polish athletes. The findings add to an evidentiary line which shows significant associations between self-reported SRL in sport practice and markers of sport expertise (e.g., Toering et al., 2009; Wilson et al., 2021), including specifically with the Short Form SRL-SP (Wilson et al., 2019).

Regarding concurrent validity, our results supported the expectation that both motivational and metacognitive subscales would be positively and substantially correlated with general self-efficacy. The strongest

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TABLE 1 Mean, standard deviations, standard error, variance, and factor loadings based on the confirmatory factor analysis.

Item	*M*	*SD*	SE	Variance	Factor loadings	
					Metacognition	Motivation
1. I try to understand the goal of a practice task before I do it.	5.50	1.33	0.07	1.77	0.56	
2. I consciously have goals in mind for how hard I want to work at practice.	5.97	1.18	0.07	1.38	0.56	
3. I check how well I am doing during practice tasks.	5.75	1.13	0.06	1.28	0.52	
4. I clearly plan my course of action before starting practice tasks.	5.26	1.31	0.07	1.70	0.57	
5. During practice, I consciously have goals in mind to improve how I train.	5.86	1.16	0.06	1.34	0.59	
6. I reflect upon my actions at practice to see whether I can improve them.	5.82	1.17	0.06	1.37	0.64	
7. Before I do a practice task, I think through the steps in my mind.	5.37	1.32	0.07	1.75	0.61	
8. When thinking about my practice, I reflect about my strengths and weaknesses.	5.21	1.48	0.08	2.20	0.56	
9. I develop a plan for resolving difficulties at practice.	4.85	1.37	0.08	1.88	0.64	
10. After finishing, I look back on practice tasks to evaluate my performance.	4.74	1.56	0.09	2.44	0.66	
11. Even when I do not like a task during practice, I work hard.	5.69	1.20	0.07	1.45		0.68
12. When facing difficulties at practice I can rely on my coping abilities.	5.61	1.05	0.06	1.09		0.64
13. I am confident that I can deal efficiently with unexpected events at practice.	5.43	1.10	0.06	1.21		0.65
14. I usually keep working hard even when sport training tasks become difficult.	5.95	1.03	0.06	1.07		0.70

Factor characteristics							
Factor	*M* of Total Score (*SD*)	*M* of Average Score (*SD*)	AVE	Unrotated solution		Rotated solution	
				Sum Sq loadings	Proportion variance	Sum Sq loadings	Proportion variance
Metacognition	54.34 *(8.48)*	5.43 *(0.85)**	0.35	4.82	0.35	3.14	0.22
Motivation	22.68 *(3.38)*	5.67 *(0.84)**	0.45	0.88	0.06	2.57	0.18
Cumulative variance					0.41		0.41

Cronbach's α for the metacognitive and motivational subscales were.85 and.77, respectively; AVE – Average Variance Extracted. Total scores are out of 70 for metacognition, out of 28 for motivation; *average score for each factor on a 1–7 scale.

correlations, of medium effect size (Ellis, 2010), were between the Short Form SRL-SP subscales scores and GSES scores. The correlation between GSES and the motivational subscale was higher (0.48, nearing a large effect) than the correlation with the metacognitive subscale, which is intuitive considering the motivational subscale shares more content with the GSES around capacity beliefs, confidence, and coping competencies. Theoretically, individuals who believe that they are more capable of performing domain behaviors are more motivated and more likely to be interested in the task (Blecharz et al., 2014). Self-efficacy and capacity beliefs also motivate decisions to initiate an action, the amount of effort athletes will invest, and how long they will persist in behaviors when difficulties appear, all aspects of motivated self-regulation (Rogowska et al., 2022). The correlation between GSES and the metacognitive subscale is interpretable in that more efficacious athletes choose more

adaptive practice strategies, including formulating specific goals, and self-evaluating to make attributions for learning (Cleary and Zimmermann, 2001).

A medium-sized correlation was found between the Short Form SRL-SP metacognitive subscale score and metacognitive self, that is, athletes' report of self-awareness of their self-regulatory biases (Kleka et al., 2019). Biases are personalized tendencies of thinking (Brycz and Karasiewicz, 2011) that are influential in self-regulation of practice. For example, some people have metacognitive biases that lead them to underestimate the time required to achieve a goal or accomplish a task, or to overestimate probability of one's future success (Kleka et al., 2019), whereas other biases include tendencies to focus on factors facilitating goal pursuit while allocating away from obstacles or evaluation of mistakes (Buehler et al., 1994). A strong metacognitive self, as indicated by MCS-24 scores, indicates individuals have enhanced cognitive capacity for metacognitive skills in learning about oneself (Kleka et al., 2019), thus the medium-sized correlation is evidence of concurrent validity. There was a small-sized correlation between MCS-24 scores and the motivational subscale, which is intuitive, seeing that Kleka et al. (2019) described how a strong meta-cognitive self was associated with a strong motivation to learn about oneself.

In regard to action vs. state orientation subscales, there was little evidence of concurrent validity with the Short Form SRL-SP subscales. Only one relationship provided significant, the small-sized correlation between the AOF subscale (failure-related action orientation vs. preoccupation) and the motivational subscale. Thus, when athletes indicated a greater capability to refocus following failure/disappointment and to dismiss/disrupt bothersome cognitions, they also reported greater use of self-motivation processes to recruit personal effort and cope with difficulties when tasks become hard. This significant correlation is intuitive because action-control orientation becomes increasingly valuable when individuals confront demands and require resilience during goal-oriented tasks (Gröpel et al., 2014), as would be the case when practice becomes unpleasant and athletes are faced with inhibitory control over temptations to quit hard, deliberate practice (Tedesqui and Young, 2015). One explanation for why this correlation is not stronger may be that survey-based methods have limits in effectively priming respondents to consider the essence of challenge, demands, or threats during a goal-oriented task. This has been noted by action-control researchers, for example, who have used ego-depleting exertion tasks and standardized vigilance tasks to better understand the effects of an individual's tendencies for action orientation (e.g., Gröpel et al., 2014). The remaining non-significant correlations between action-control scales and the Short Form SRL-SP subscales might also be explained similarly, that survey methods may have their limits in establishing concurrent validity, when the theoretical construct being assessed might depend on *in situ* priming of significant challenges, or hardship, or ruminating bothers, for individuals to manifest self-regulated decision-making (and not hesitation) and continued on-task regulation (rather than volatility).

Our large, mixed-sport sample may also have been unsuited to show the concurrent validity we expected. For example, Beckmann and Kazén (1994) described how associations between action-control orientation scores and key phenomena are complex and can vary substantially by sport type. Whether a sport is "impulsive," "controlled," whether it is "feedback" (which would require more dynamic and constant self-regulation) or "flow"-based (see Beckmann and Kazén, 1994), could moderate correlations between the Short Form SRL-SP measures and action-control scale scores. For instance, athletes with high AOF perform better in "feedback" type sports disciplines, whereas the opposite trend is observed for "impulsive" sport athletes (i.e., long jump, high jump, javelin; Beckmann and Kazén, 1994). Although we recruited intensively and pragmatically required a mixed-sport sample to satisfy sample size requirements for the various statistical tests, we could not pursue any questions about specific sport types, which is a limitation, and which could be an important area of future research."

Limitations and future research

Although a strength of this investigation was the use of four escalating skill, allowing for more discriminating inferences on the role of SRL processes toward skill group membership, a limitation was the absence of cross-validation of such groups using secondary performance measures or coach ratings. The current study did not specifically assess SRL measures, or the other concurrent measures for that matter, in relation to indices of practice. Indeed, the current study did not examine how differences in amounts of sport-specific practice contribute to sports-level group status, which may be viewed as a limitation. To most fully validate the role of SRL measures in enhancing practice among Polish athletes, studies should be conducted to examine the relation between report on the Polish Short Form SRL-SP and amounts of practice and particularly in relation to indices of quality/purposeful sport practice. Additionally, future researchers could consider examining how Short Form SRL-SP measures mediate the relationship between sport-specific practice and sports-level group status. Finally, there are limits to cross-sectional analyses such as those employed in the current investigation; thus, longitudinal studies are needed to determine causality and effectiveness of SRL processes on the acquisition of better sport performances.

Given how mixed results for concurrent and psychometric validity were contextualized by the strong evidence for criterion validity, it seems reasonable for future research to inquire about the practical validity of the Polish Short Form SRL-SP. Practical validity refers to the consideration of how research findings/products, in our case the Polish Short Form SRL-SP, are informed by the perspectives of practitioners, located within the narratives of applied practice, and examined instrumentally by those in practice. Young et al. (in press) made the case that such practical validity—evidence for the merits of how an SRL survey can be used as a tool for development, self-learning, and as a catalyst for discussions between athletes and practitioners (e.g., coaches, sport psychology consultants), is a future area of understanding. We agree that this would be valuable for the Polish Short Form SRL-SP, especially given Wilson et al. (2019) purposeful inclusion of consultants' perspectives in the initial vetting of the English short form to ensure that it could be subjected to examination in practical settings. Further, it is worth examining how our findings extend to younger samples since more evidence is needed to better understand if SRL is a sport-specific skill that can be taught or an individual disposition discriminating among athletes at different competitive levels.

Conclusion

Altogether, the multiple forms of validation used in our study provided promising results for the use of a Short Form SRL-SP

TABLE 2 Inter-group data for scores on the metacognitive and motivational subscales of the Polish Short Form SRL-SP.

Factor	Competitive level	Mean total score / mean of average score (*SD*)*	*Post-hoc* Dunn test statistics			
			Between-group comparisons	*Z*	*p*	*D*
Metacognitive score	Amateurs	52.02 *(8.65)* / 5.20 *(0.86)*	Amateurs–Regional	−0.758	0.224	0.170
	Regional	53.45 *(8.04)* / 5.34 (0.80)	Amateurs–National	−2.282	0.011	0.360
	National	55.21 *(9.00)* / 5.52 *(0.90)*	Amateurs–International Elite	−3.442	< 0.001	0.758
	International Elite	57.89 *(6.33)* / 5.79 *(0.63)*	Regional - National	−1.900	0.029	0.211
			Regional–International Elite	−3.217	< 0.001	0.589
			National–International Elite	−1.914	0.028	0.319
Motivational score	Amateurs	21.13 *(3.38)* / 5.28 *(0.85)*	Amateurs–Regional	−2.517	0.006	0.370
	Regional	22.40 *(3.48)* / 5.60 *(0.87)*	Amateurs–National	−3.810	< 0.001	0.621
	National	23.21 (3.33) / 5.80 *(0.83)*	Amateurs–International Elite	−4.383	< 0.001	1.076
	International Elite	*24.25 (1.87) / 6.06 (0.47)*	Regional–National	−1.609	0.054	0.235
			Regional–International Elite	−2.769	0.003	0.576
			National–International Elite	−1.665	0.048	0.341

Total scores are out of 70 for metacognition, out of 28 for motivation; *average score for each factor on a 1–7 scale.

TABLE 3 Spearman rho correlations between age, the short form SRL-SP subscales, and measures of metacognitive self, general self-efficacy, and action-control subscales.

Variable	1	2	3	4	5	6	7
15. Age	—						
16. MCS-24	0.15*(0.02)	—					
17. GSES	0.07	0.28***(0.08)	—				
18. Metacognitive SRL-SP	0.11	0.40***	0.41***(0.17)	—			
19. Motivational SRL-SP	−0.02	0.25***	0.48***	0.55***(0.30)	—		
20. AOF	0.05	−0.16*	0.30***	−0.06	0.26***(0.06)	—	
21. AOD	0.04	−0.01	0.33***	0.03	0.12	0.31***(0.10)	—
22. AOP	0.14	0.13	0.02	0.10	0.08	−0.07	0.31***(0.10)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; Numbers in parentheses along the diagonal represent R^2 values for discriminant validity analyses; AOF = Failure-related action orientation vs. preoccupation subscale; MCS-24 = Metacognitive self-scale; GSES = General self-efficacy scale; AOD = Decision-related action orientation vs. hesitation subscale; AOP = Performance-related action orientation vs volatility subscale.

version among Polish athletes. The results provided evidence for very good criterion validity, showing that scores on the survey resulted in stronger and more consistent skill group differences, corresponding completely across all escalating skill groups, than all prior research works using SRL surveys. Our findings suggest that generally greater engagement in metacognitive and motivational processes of SRL distinguishes the most elite group from lesser-skilled groups. There are also differences between amateur-, regional- and national-level athletes. Evidence toward concurrent validity seemed mixed. On the one hand, we found medium-sized correlations with self-efficacy, and medium and small-sized correlations with metacognitive self, yet the concurrent validity in relation to action control was less robust, with only a small-sized correlation between the failure-related action orientation vs. preoccupation subscale and the motivational SRL-SP subscale.

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 University of Physical Education in Krakow (grant 219/BS/INS/2019). The patients/participants provided their written informed consent to participate in this study.

Author contributions

MS was responsible for the conceptualization of the research, the research design, participant recruitment, data collection and analysis, statistical analysis, and was a primary contributor to the writing of the first manuscript draft. SW contributed to the data analysis, statistical analysis, and the writing of the manuscript. JB contributed to the research design, was responsible for participant recruitment, and applied his expertise in sport psychology across the manuscript with a focus on the application to sport practice. BY contributed to the data analysis, statistical analysis, and the writing of the manuscript, and edited the final manuscript. All authors contributed to the article and approved the submitted version.

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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.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1132608/full#supplementary-material

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Comparison of personality differences of Polish mountaineers

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A noticeably increased interest in mountain climbing, both as the form of extreme sport and a form of tourism, has been observed in Poland recently. The assumption of this study is that practicing different varieties of mountaineering influences the personality of Polish climbers in a different manner. The aim of the research was to compare the personality differences of Polish mountaineers. To this aim, the population of Polish high-performance mountaineers was studied (N =81; including 39 women and 42 men). Due to the type of mountaineering practiced, the respondents were divided into Alpine climbers (n =48) and Himalayan climbers (n =33). The average age of the surveyed climbers is 33.85years. The Big Five model was used including the NEO-FFI Personality Questionnaire and the analyzes were performed using the IBM SPSS Statistics statistical method package, version 27.0. Statistically significant differences were noted only for agreeableness $F(1.77)=5.05$, p =0.027. The Alpine climbers showed a higher level of agreeableness than the Himalayan climbers. After taking into account the Sidak amendment, significant differences in the level of agreeableness were found only among women. Comparisons between other personality traits were not statistically significant. There is a significant difference between the personalities of Polish Alpine climbers and Polish Himalayan climbers in the dimension of agreeableness only among women: female Alpine mountaineers are more agreeable than Himalayan mountaineers. It was presumed that in terms of ethics in the high mountains, the social competences of Alpine mountaineers are much more developed than that of Himalayan mountaineers.

KEYWORDS

sports psychology, Big Five, mountaineering, Alpine climbing, Himalayan climbing, innovative agonology

Introduction

The mountains have fascinated people for centuries. Those living at the foot of the mountains worshiped them. Some of these beliefs have survived to this day and still play an important role in the highlander community (Jeong et al., 2002). Mountains are defined as parts of land located at higher altitudes than the highlands and lowlands, separated from them by natural boundaries. When classifying mountain heights, one takes into account the characteristic altitudinal zonation of fauna and flora, the presence of large differences in relative altitudes or the absolute height above sea level (Wierciński, 2021). In sports theory, it is assumed that the peaks of the low mountains are up to 1,000 m above sea level, the middle mountains are at an altitude of 1,001–2,500 m, and the high mountains are above 2,500 m above sea level (Kosendiak, 2005).

Physical activity in the high mountains is called mountaineering or alpinism. It is understood as climbing difficult climbing routes, walls and ridges at high altitudes (Biswas et al., 2022). In Poland the following basic varieties of high mountain climbing are distinguished, with respect to the terrain difficulties and locations: mountaineering practiced in the Tatra Mountains (over 2,000 m above sea level); Alpine mountaineering (over 4,000 m above sea level); and Himalayan mountaineering (over 7,000 m above sea level) (Kosendiak, 2005). It is an extreme sport in which success depends on proper preparation, appropriate knowledge and experience. An inseparable element of mountaineering is preparation for specific weather conditions and threats coming from the surrounding terrain, and the selection of the necessary equipment (Żoczek et al., 2017) as well as the choice of the appropriate company. The basis for a mountaineering expedition preparation is comprehensive physical training (Prokopczyk and Wochyński, 2022). It is based mainly on endurance and strength components (Prokopczyk and Sokołowski, 2022) and targeted climbing training (Hamid et al., 2017). Mental training is also equally important and includes concentration, emotional control and mental resistance exercises (Piepiora et al., 2022a). It should be noted here that mountain climbing with the use of oxygen devices is no longer considered to be an extreme sport, but qualified mountaineering tourism (Pomfret, 2006) or active tourism (Corneliu et al., 2012). Qualified mountaineering tourism is associated with a high frequency of undertaking such expeditions while active tourism is characterized by the occasional nature of undertaking such expeditions and their hobby-like nature (Żiżka-Salamon and Gąsienica-Walczak, 2011). Recent decades have seen an increase in the popularity of high-mountain tourism, for instance commercial expeditions to the highest mountain peaks (Białecka, 2011). Regardless of the adopted forms of mountaineering, staying at high altitudes and being exposed to numerous stress factors during expeditions have a significant impact on the climbers' physical and mental health. Positive effects on vitality, musculoskeletal and cardiorespiratory development and mental relaxation have been observed (Żurek et al., 2022). Mountaineering also has great cognitive value related to exploration and strong emotional experiences. An additional aspect is the closeness to nature and the hedonistic value, due to the participation in a given activity in high mountain terrain (Sołtysik et al., 2018). Participants' motives for undertaking high-mountain activities refer to feelings of happiness and pleasure, positive reinforcement and character formation (Paudyal et al., 2022). The need for solitude and isolation from the outside world and overcoming one's own limitations is also noted (Sołtysik et al., 2019). An important social aspect is the achievement of set goals and the satisfaction of the need for respect and affiliation (Skrzypińska and Atroszko, 2015). A review of a climber's basic motives provides an individualization of his or her mental training (Chen et al., 2012).

The above-mentioned issues form the basis for research in the field of sports psychology into the personality of mountain climbers. The point of reference here is personality, which is shaped by life experiences, contacts with people who are important to a given individual, social roles played by a given person, as well as repetitive or exceptionally intense events (Allen et al., 2013). Previous studies show that the personality of mountain climbers is typical of sportspeople: low neuroticism, high extraversion, average openness to experience and agreeableness, high conscientiousness (Piepiora, 2019). It is worth noting that athletes are distinguished from non-training people by low neuroticism, higher extraversion, openness to experience, agreeableness and conscientiousness (Steca et al., 2018). Moreover, sports champions are distinguished from other athletes by one dominant factor. In the Polish sportspeople population, according to the existing research, this is even lower neuroticism (Piepiora and Piepiora, 2021); in the Australian population, this is even higher extraversion (Allen et al., 2021); in the Turkish population is an even greater openness to experience (Tok, 2011); while in the Iranian population, this is even greater conscientiousness (Mirzaei et al., 2013).

With the above in mind, it was decided to investigate the personality of Polish mountaineers. As Alpine mountaineering and Himalayan mountaineering are characterized by physical activity at different altitudes, it was considered that this may be evident in the personality of these two groups of high altitude climbers. It was assumed that there exist personality differences of Polish climbers depending on the variety of mountaineering performed. Therefore, the aim of the study was to compare the personality differences of Polish Alpine and Himalayan climbers. A hypothesis was adopted that there are significant differences between the personality of Polish Alpine and Polish Himalayan climbers. It was assumed that Himalayan climbers should be characterized by lower neuroticism and higher openness to experience and conscientiousness than Alpine climbers, because the former activity is more dangerous and technically more difficult than the latter. Consequently, an answer to a question as to possible differences existing between Polish Alpine climbers and Himalayan climbers was sought.

Methodology

Researched persons

The population of Polish mountaineers ($N = 81$), including 39 women and 42 men, members of the Polish Mountaineering Association, was surveyed. All respondents agreed to participate in the study and declared that they practice an extreme sport without oxygen devices. Before taking part in the survey, respondents had to specify what type of mountaineering they undertook. On this basis, the respondents were divided into Alpine climbers ($n = 48$) and Himalayan climbers ($n = 33$). Their age ranged between 20 and 49 years, their average age was 33.85 years (SD = 7.36).

Method

The five-factor model of personality was used as a research method. It is more widely known as the 'Big Five' (McCrae and Costa, 1987). It consists of five traits defined on the basis of factor analysis: neuroticism, extraversion, openness to experience, agreeableness, conscientiousness (McCrae and Costa, 1997). Neuroticism is understood as susceptibility to experiencing negative emotions. It consists of: anxiety, angry hostility, depression, impulsiveness, vulnerability, self-consciousness. Extraversion, on the other hand, is a dimension relating to the quality and quantity of social interactions, activity level, energy, ability to feel positive emotions. It consists of: gregariousness, warmth, assertiveness, activity, excitement seeking, positive emotions. The individual's tendency toward exploration, positive valuing of life experiences, tolerance toward novelty and

cognitive curiosity is regarded as openness to experience. This dimension consists of: fantasy, aesthetics, feelings, actions, ideas, and values. The dimension that characterizes the attitude toward other people, the interpersonal orientation experienced in feelings, thoughts, action – is agreeableness. It consists of: trust, straightforwardness, altruism, compliance, modesty, tendermindedness. The last dimension is conscientiousness. It characterizes the degree of organization, perseverance, motivation of an individual in goal-oriented activities and describes a person's attitude towards work. It consists of: competence, order, dutifulness, achievement striving, self-discipline, deliberation (Costa et al., 2001). The NEO-FFI Personality Questionnaire (Costa and McCrae, 2007) was used to conduct the study. It consists of 60 self-report statements. There are 12 statements for each dimension. On a five-point scale: (1) strongly disagree; (2) disagree; (3) have no opinion; (4) agree; (5) strongly agree; the intensity of each trait is measured. Each answer can be scored from 0 to 4 points. This means that a maximum of 48 points can be obtained on a given Big Five dimension. The NEO-FFI has sex-and age-dependent norms: 15–19, 20–29, 30–39, 40–49, and 50–80 years. The raw scores obtained are then converted into stens. Each Big Five trait is considered on a scale of 1 to 10 stens. Low scores are considered to be those between 1 and 3 sten. Moderate scores are between 4 and 6 sten. When scores between 7 and 10 sten are obtained, the results are interpreted as high.

Procedure

The study was conducted between October 2021 and March 2022. The research was conducted online due to the COVID-19 pandemic restrictions in force in Poland at the time. The criterion for inclusion in the study was the voluntary willingness of the members of the Polish Mountaineering Association to participate. Subjects had 1 h to work with NEO-FFI questionnaire. The SURVIO software was used for conducting the Computer Assisted Web Interview research method. Each of the Polish mountain climbers belonging to Polish Mountaineering Association, received temporary access to the NEO-FFI questionnaire *via* e-mail, along with a request to complete it. All respondents consented to the processing of the obtained results for the scientific research purposes and read the filling instructions before commencing the questionnaire. The project was carried out following the positive opinion of the Senate Committee for Research Ethics at Wrocław University of Health and Sport Sciences number 20/2019.

Statistical analysis

The respondents' answers were organized using Excel spreadsheet. Statistical analyses were carried out using IBM SPSS Statistics 27.0 software. The program performed an analysis of basic descriptive statistics and a two-way ANOVA analysis of variance. The level of statistical significance in the following section was assumed at $\alpha = 0.05$. The sensitivity analysis for the compute required effect size of the statistical test was performed, assuming the size of the research sample equal to $N = 81$, level of $\alpha = 0.05$ and the statistical power of the test corresponding to 80% (G*power) it is possible to detect effect size $\eta p2 = 0.09$ (Cohen's $f = 0.31$).

Results

As a first step, the basic descriptive statistics of the subjects were analyzed, together with the interpretation of the mean intensity of personality traits based on the Polish NEO-FFI norms. Sex differences were taken into account. Therefore, the analyses used results converted into stens according to the current Polish NEO-FFI norms (Table 1).

In the second phase, the assumptions of the two-factor analysis of variance were tested. An analysis of normality of distribution was performed by group of Alpine climbers and Himalayan climbers. The analysis showed that the distribution of the variables was close to a normal distribution ($p > 0.050$) with the exception of openness to experience among women in the Alpine mountaineering group, agreeableness among women in the Alpine mountaineering and Himalayan mountaineering groups and conscientiousness among men in the Himalayan climbers group (Table 2). Additionally, homogeneity of variance ($p > 0.050$) was observed across groups for all personality traits. Therefore, it was considered appropriate to use a two-factor analysis of variance.

In the next step, it was tested whether Alpine mountaineers and Himalayan mountaineers differed in the intensity of individual personality traits. A two-factor analysis of variance was performed in which the independent variable was group (Alpine climbers vs. Himalayan climbers) and sex (female vs. male). Thus, both the effect of group and sex in the severity of individual personality traits were tested. Before proceeding with the analysis, the chi-square test was used to check that the groups were equal. The analysis showed that there were no statistically significant differences in the number of individuals in each group, $\chi^2(1) = 0.16$, $p = 0.821$. Detailed results of main effects and interactions are presented in Table 3, while the results of the pairwise comparisons test are presented in Table 4, and the confidence intervals in Table 5.

The analysis showed a significant main effect for agreeableness $F(1.77) = 5.05$; $p = 0.027$. Alpine climbers ($M = 6.30$; SD = 2.30) have higher levels of agreeableness than Himalayan climbers ($M = 5.64$; SD = 2.20). However, there was no significant effect of sex or interaction of group with sex. Interestingly, pairwise comparisons with the Sidak correction showed that, when controlling for sex, significant differences in levels of agreeableness were only observed among women. The main effect of sex for openness to experience and the main effect of sex for conscientiousness were at the limit of statistical significance. They are not described because these effects are statistically insignificant.

Discussion

Nowadays, there is a great increase in interest in mountaineering (Krzemieniecki and Barczyński, 2019) as developments in technology have made its much more accessible (Cieśliński et al., 2016). Nevertheless, its varieties still differ in the degree of potential health and life threat (Piepiora and Piepiora, 2020; Piepiora Z. et al., 2022). Mountaineers report that they often give up other activities to undertake this form of activity (Ryn, 1969): training and climbing trips are a life priority for these individuals (Skorupa and Draga, 2012). Thus, passion and lifestyle come to the fore (Cronin, 1991). Moreover, risky mountaineering can be addictive (Paszkiewicz, 2016). It is mostly practiced in teams, therefore climbers' social competences should

TABLE 1 Basic descriptive statistics for individual personality traits of mountaineers.

	M	Mdn	SD	Sk.	Kurt.	Min	Max	Interpretation of the average severity of the trait
Neuroticism	4.57	4.00	2.16	0.36	−0.56	1.00	10.00	Moderate
Extraversion	6.25	6.00	2.34	−0.29	−0.50	1.00	10.00	Moderate
Openness to experience	6.81	7.00	2.09	0.04	−1.07	3.00	10.00	High
Agreeableness	6.30	6.00	2.30	−0.31	−0.24	1.00	10.00	Moderate
Conscientiousness	5.56	6.00	1.98	−0.12	0.23	1.00	10.00	Moderate

M, mean; Mdn, median; SD, standard deviation; Sk., skewness; Kurt., kurtosis; Min, minimum value; Max, maximum value.

TABLE 2 Results of the normality of distribution test for individual personality traits by group.

	Alpine climber				Himalyan climber			
	Female (*n* =24)		Male (*n* =24)		Female (*n* =15)		Male (*n* =18)	
	S-W	*p*	S-W	*p*	S-W	*p*	S-W	*p*
Neuroticism	0.95	0.250	0.94	0.079	0.93	0.270	0.90	0.056
Extraversion	0.97	0.155	0.91	0.056	0.96	0.725	0.92	0.123
Openness to experience	0.87	0.006	0.96	0.165	0.88	0.056	0.94	0.281
Agreeableness	0.91	0.043	0.92	0.176	0.85	0.019	0.95	0.460
Conscientiousness	0.94	0.699	0.88	0.041	0.92	0.209	0.88	0.030

S-W, Shapiro–Wilk normality test; *p*, significance level.

TABLE 3 Coefficients of the two-factor analysis of variance model for individual personality traits.

Model	Effect		df1	df2	*F*	*p*	η_p^2	η^2
Neuroticism	Main	Sex	1	77	2.33	0.131	0.029	0.029
		Group	1	77	0.41	0.526	0.005	0.005
	Interaction	Sex * group	1	77	1.41	0.240	0.018	0.017
Extraversion	Main	Sex	1	77	0.65	0.422	0.008	0.008
		Group	1	77	1.20	0.278	0.015	0.015
	Interaction	Sex * group	1	77	0.04	0.838	0.001	<0.001
Openness to experience	Main	Sex	1	77	3.75	0.056	0.046	0.044
		Group	1	77	1.62	0.207	0.021	0.019
	Interaction	Sex * group	1	77	1.95	0.166	0.025	0.023
Agreeableness	Main	Sex	1	77	0.02	0.879	<0.001	<0.001
		Group	1	77	**5.05**	**0.027**	**0.062**	0.060
	Interaction	Sex * group	1	77	2.20	0.142	0.028	0.028
Conscientiousness	Main	Sex	1	77	3.95	0.050	0.049	0.049
		Group	1	77	0.02	0.874	<0.001	<0.001
	Interaction	Sex * group	1	77	0.16	0.689	0.002	0.002

Bold values indicate statistically significant results. df, degrees of freedom; F, ANOVA test statistic; *p*, statistical significance; η_p^2, partial η^2; η^{2-}, eta square.

be developed to a high degree (Bermúdez, 1999). Consequently, discussions on ethical issues applicable in high mountains are still a contentious issue (Vollrath and Torgersen, 2002). It remains an individual matter for modern climbers whether reaching the summit is more important than the 'brotherhood of the rope' and the life of another person in a critical situation (Castanier et al., 2011). It should be noted that those who undertake high altitude climbing are knowingly taking a risk to their health or life (Heska-Kwaśniewicz, 2019).

By referring the above issues to our research results, only one significant difference between the personalities of Polish Alpine climbers and Polish Himalayan climbers was noted in the study. It was in the agreeableness dimension, and only between women. Female Alpine climbers were shown to have significantly higher agreeableness than female Himalayan climbers. Female Alpine climbers have high levels of openness to experience and agreeableness and moderate levels of neuroticism, extraversion, and conscientiousness. In contrast,

TABLE 4 Mean values and standard deviations with pairwise comparisons tests for simple effects.

	Alpine climber				Himalayan climber			
	Female (n =24)		Male (n =24)		Female (n =15)		Male (n =18)	
	M	SD	*M*	SD	*M*	SD	*M*	SD
Neuroticism	4.33	2.33	4.50	2.23	4.07	1.83	5.39	2.03
Extraversion	6.21	2.41	6.75	2.36	5.73	2.19	6.06	2.41
Openness to experience	7.21	1.84	6.96[c]	2.16	7.27[a]	2.25	5.72[ac]	1.96
Agreeableness	7.17[a]	2.37	6.33	1.99	5.27[a]	2.63	5.94	2.04
Conscientiousness	5.96	2.07	5.25	1.65	6.07	1.71	5.0	2.37

[a]Statistically significant Sidak-corrected pairwise comparison results (simple effects); [c] Sidak-corrected pairwise comparison results $p = 0.056$.

TABLE 5 Results of pairwise comparisons with confidence intervals.

		Neuroticism	Extraversion	Openness to experience	Agreeableness	Conscientiousness
		CI difference (95%)	CI difference (95%)	CI difference (95%)	CI difference (95%)	CI difference (95%)
Female	Male	−0.74 (−1.72–0.23)	−0.43 (−1.50–0.63)	0.90 (−0.02–1.82)	0.08 (−0.94–1.09)	0.89 (−0.01–1.78)
Alpine climber	Himalayan climber	−0.31 (−1.28–0.66)	0.58 (−0.48–1.65)	0.59 (−0.33–1.51)	**1.14 (0.13–2.16)**	0.07 (−0.82–0.96)
Female Alpine climber	Male Alpine climber	−0.17 (−1.40–1.07)	−0.54 (−1.90–0.81)	0.25 (−0.92–1.42)	0.83 (−0.46–2.12)	0.71 (−0.42–1.84)
Female Himalayan climber	Male Himalayan climber	−1.32 (−2.82–0.18)	−0.32 (−1.96–1.32)	**1.54 (0.12–2.97)**	−0.68 (−2.24–0.89)	1.07 (−0.30–2.44)
Male Alpine climber	Male Himalayan climber	−0.89 (−2.22–0.45)	0.69 (−0.77–2.16)	1.24 (−0.03–2.50)	0.39 (0.43–3.37)	0.25 (−0.97–1.47)
Female Alpine climber	Female Himalayan climber	0.27 (−1.14–1.68)	0.47 (−1.07–2.02)	−0.58 (−1.40–1.28)	**1.90 (0.43–3.37)**	−0.11 (−1.40–1.18)

Bold values indicate statistically significant results. Difference, difference of averages; CI, 95% confidence interval for the difference.

female Himalayan climbers have high levels of openness to experience and other Big Five dimensions at moderate levels. Alpine climbers, on the other hand, show high levels of extraversion and openness to experience and the other personality traits are at moderate levels. Interestingly, Himalayan climbers are distinguished by moderate levels of all personality traits. Discussing the obtained results, it was noted that the personality traits of Polish mountaineers are distributed differently. They are determined by the variety of climbing – Alpine or Himalayan – and the sex of those undertaking this type of competitive sport. But there is a statistically significant difference only between the levels of agreeableness of Polish female Alpine climbers and female Himalayan climbers: the former have a higher agreeableness than the latter. Thus, they are more positive towards other people. They are interpersonally oriented toward altruism being guided in their behavior by the good of others and are willing to make sacrifices. They experience this in their feelings, thoughts and actions. With regard to ethical issues in the mountains, it is reasonable to believe that female Alpine mountaineers have a greater tendency to stick with the group and provide assistance in critical situations. It has been found that the social competence of female Alpine climbers in high mountains is developed much more than that of female Himalayan climbers. And the latter, in turn, like male high-mountain climbers, are moderately agreeable. They are characterized by balanced altruism versus antagonism. From this perspective, it is reasonable to think that Polish Himalayan climbers and Polish male Alpine climbers, depending on their current priorities in the mountains, will stick together as a group and provide assistance in critical situations or they will not do so. In this sense, one can speak of hostility resulting from conflicting interests and a desire to compete. The results obtained confirm the individual issues of ethical dilemmas in high mountains (Ewert, 1994; Cooper et al., 2000; Woodman et al., 2008).

Other occurring personality differences of Polish mountaineers are not statistically significant. It is important that the personality of people practicing mountaineering is modified by the specificity of this extreme sport (Piepiora, 2021; Piepiora et al., 2022b). But the reports of other researchers (Gray, 1968; Freixanet, 1991; Clarke and Robertson, 2005; Monasterio et al., 2014; Sołtysik et al., 2019) stating that depending on the varieties of high-mountain climbing and cultural factors (nationality), the personality traits of people undertaking different varieties of high-mountain climbing are distributed differently, are also valid. It has been noted that despite these differences, in general, high-mountain climbers tend to seek adventure and risk (Self et al., 2007; Llewellyn and Sanchez, 2008; Castanier et al., 2010; Kalina, 2020). A similar trend is noted in the Far Eastern martial arts, where, in a direct confrontation between two competitors, the self-improvement of practitioners is prioritized

(Litwiniuk et al., 2009, 2019). Moreover, high-mountain climbing did not lose its popularity in Poland during the COVID-19 pandemic (Klimczak et al., 2021; Fedyk et al., 2022a,b).

Limitations of the research

The present study is limited in time and space to the surveyed Polish population of high altitude climbers. The obtained results cannot be related to the whole Polish, European or world population of high altitude climbers. They only allow us to formulate regularities relating to specific locations – the Alps and the Himalayas – and to the individual experiences of the people surveyed.

Conclusion

There is a significant difference between the personalities of Polish Alpine climbers and Polish Himalayan climbers in the agreeableness dimension only among women. Female Alpine mountaineers are characterized by higher agreeableness than female Himalayan climbers. Himalayan climbers are otherwise not distinguished from Alpine climbers by lower neuroticism and higher openness to experience and conscientiousness. The recorded score in agreeableness was found to relate to ethical issues in the high mountains: the social competences of female Alpine climbers are considerably more developed than those of female Himalayan climbers.

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 Senate Committee for Research Ethics at Wrocław University of Health and Sport Sciences number 20/2019. The patients/participants provided their written informed consent to participate in this study.

Author contributions

PP and JN contributed to conception and design of the study and organized the database. PP performed the statistical analysis. PP, JB, and ZP wrote the first draft of the manuscript. PP, JB, KW, and ZP wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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.

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Impact of marathon performance on muscles stiffness in runners over 50years old

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Introduction: The research examines the relationship between marathon performance and muscle stiffness changes from pre to marathon in recreational runners aged 50+ years.

Methods: Thirty-one male long-distance runners aged 50–73 years participated in the experiment. The muscle stiffness of quadriceps and calves was measured in two independent sessions: the day before the marathon and 30min after the completed marathon run using a Myoton device.

Results and Discussion: The 42.195-km run was completed in 4.30,05 h ± 35.12 min, which indicates an intensity of 79.3% ± 7.1% of HRmax. The long-term, low-intensity running exercise (marathon) in older recreational runners and the low level of HRmax and VO2max showed no statistically significant changes in muscle stiffness (quadriceps and calves). There was reduced muscle stiffness (p = 0.016), but only in the triceps of the calf in the dominant (left) leg. Moreover, to optimally evaluate the marathon and adequately prepare for the performance training program, we need to consider the direct and indirect analyses of the running economy, running technique, and HRmax and VO2max variables. These variables significantly affect marathon exercise.

KEYWORDS

sport, marathon, muscle stiffness, running economy, endurance performance, older-age runners

1. Introduction

Preparing long-distance runners, especially recreational runners and those over 50, to participate in marathons (Ahmadyar et al., 2015) requires a rational strategy of training (Laursen and Jenkins, 2002). This mainly applies to developing the runner's motor abilities, technical skills, and probably the two most important actions: tactical skills and adequate dietary

supplementation during the marathon itself (Keogh et al., 2019; Chmura et al., 2020; Doherty et al., 2020). Tactical skills refer to the o proper distribution of the body's physical capabilities over a distance. Modern long-distance training has to allow runners to sustain specific loads of long duration. Therefore, continuous running and increased fatigue may cause a runner to experience physiological changes that either enhance or diminish their performance or make it impossible to continue the run (Dotan et al., 1983; Alvero-Cruz et al., 2020; Keogh et al., 2020). Adequate training planning for marathons involves selecting appropriate training methods, maintaining a rational relationship between training loads, competition loads, good recovery, and proper pre-and post-workout supplementation (Hansen et al., 2014).

Most marathon long-distance training programs, especially master runners, are based on regular long, mainly in the aerobic area, runs between 20 and 40 km (Quinn et al., 2011; Casado et al., 2021). The primary purpose of such training is to develop and maintain maximum aerobic power, which is the main requirement to complete a marathon, regardless of the competitors' level of performance or age. In addition, according to Angus (2014), long-distance runs are intended to enhance running economy (RE). This teaches the athlete to run at a pace (Angus, 2014) as efficiently as possible and translates into actual running pace during the competition (Haney and Mercer, 2011; Kipp et al., 2019). Several researchers (Sproule, 1998; Kyröläinen et al., 2000; Midgley et al., 2007) claim that running economy (RE) is an aerobic demand for the maintenance of running and is referred to as the steady-state oxygen uptake (VO2) related to that speed (Quinn et al., 2011). It is known from practice that after such a long run, the athletes experience considerable muscle damage and soreness (Kyröläinen et al., 2000), which may adversely affect their muscle overload in the next training session (Berg et al., 1998).

Long-distance running competitions are associated with high mechanical stress due to damage to various muscle fibers, metabolic disorders, muscle fatigue (Joyner and Coyle, 2008), and change in muscle stiffness and elasticity (Zierath and Hawley, 2004). From the biomechanical standpoint muscle stiffness is a response to an emitted stimulus, which results from muscle resistance to mechanical lengthening (Rack and Westbury, 1969). According to Wilson et al. (1991) optimal muscle stiffness is significantly correlated with augmentation of muscle training loads.

Increasing muscle stiffness impairs muscle function and, as a consequence, reduces the body's ability to continue exercising. From a physiological point of view, muscle stiffness is strongly dependent on the size and architecture of the muscles (Brazier et al., 2014; Luu et al., 2015; Behrens et al., 2016) and their specific structural functionality (Zierath and Hawley, 2004). The physiological cross-sectional area (PCSA) was identified as one of the essential features determining muscle stiffness. Other determinants of stiffness are the type of muscle fibers and the percentage of fast-twitch and slow-twitch fibers, as the number and composition of threads, which determine the onset of fatigue and, indirectly, post-training stiffness (Seymore et al., 2017). Multiple training variables can affect muscle stiffness, including the type of muscle work performed, the muscle's functionality (flexors vs. extensors), and the amount of effort taken until recovery. There are no data on the level of muscle stiffness after prolonged exercise, especially running. It is known that in short-term, dynamic training, more significant muscle damage causes powerful eccentric contractions. Large eccentric muscle contractions during plyometric training cause more significant muscle damage than concentric ones (Kim and Lee, 2015; Wertheimer et al., 2018). This causes more delayed-onset soreness in muscles (Hody et al., 2013; Kanda et al., 2013).

While the relationship between physiological or anthropometric variables and final marathon time has been widely investigated, no study has evaluated muscle stiffness's relative contribution to marathon performance. Therefore, despite the dozen marathon investigations, there is a lack of clarity about the specific determinants of muscle stiffness on marathon performance. Thus the recipe for success – completing the marathon – remains somewhat elusive. When combined with other performance indicators previously analyzed, assessing muscle analysis would benefit runners and coaches looking to improve their marathon performance. The currently available research devices (MYOTON PRO) are so mobile and it makes reliable measurements that they can be used before and after each running activity in field conditions. Therefore, this study aimed to evaluate marathon performance and evaluate the influence of this long-term running endurance exercise on the changes in muscle stiffness in 50+ marathon runners. Therefore, this study aimed to evaluate marathon performance and evaluate the influence of this long-term running endurance exercise on the changes in muscle stiffness in middle-aged marathon runners. We hypothesize that muscle stiffness will increase with the time that the marathon lasts, no matter what level of training the runner has at the moment.

2. Materials and methods

2.1. Study design

The main objective of this study was to examine the relationship between marathon performance and changes in muscles stiffness from pre-to post-marathon in recreational runners aged 50+ years. The muscle stiffness of the quadriceps was measured in two independent sessions: the day before the marathon and 30 min after the completed marathon. Myoton measurements of each muscle group (12 points) were taken separately for the left and right legs.

2.2. Participants

Thirty-one male long-distance runners aged 50–73 years participated in the experiment. Runners estimated their training experience as 10.61 ± 8.81 years on average. The average result of the marathon run for the study group was 4.30,05 h ± 35.12 min. All participants were free from acute illness or chronic disease and did not take regular medication. The main division criterion was that the runners were over 50 years of age and had participated in at least two marathons in the previous three years. An additional measure was that all participants were actively training for long-distance running for at least one year. Each runner tested signed consent to voluntary participation in the research. Before signing informed consent forms, the participants were informed about the experiment's aim and the risk of injury. The study protocol was approved by the local Institutional Ethics Committee (Permission 36/2019 AWF Wroclaw). The research was conducted by the Declaration of Helsinki.

2.3. Marathon performance

The 37th PKO Wrocław Marathon (Wrocław, Poland, 19 September 2019) was organized by the City of Wrocław, Poland. Since the beginning of the run, The PKO Wrocław Marathon has been organized by the city of Wroclaw and is considered one of Poland's most significant running events. The PKO Wroclaw Marathon takes place annually at the beginning of September. It was sunny day of the marathon, the air temperature during the start was 21 degrees Celsius, humidity 72%, with a wind of 3.3 m/s. At the end of the run, the temperature rose to 24 degrees Celsius, humidity 46%, with a wind of 5 m/s. The data on the running time was obtained from the electronic database of the marathon's organizers. It included the number of runners who started and finished the run, the personal identification number of the run, and the place and time of the run for each participant of the marathon. The individual runtime registered in the event was automatically measured using a radio frequency identification chip system. Intermediate times every 5 km were measured for the experimental group to analyze their running pace variability accurately. In addition, the heart rate (HR) was recorded using a monitor (Polar RS300X GPS; Finland) to examine each participant during the marathon run.

2.4. Study protocol

2.4.1. Applied equipment

The Myoton PRO (Myoton AS, Estonia and Myoton Ltd., London) is a wireless hand-held device placed perpendicular to the skin over the muscle being measured. This device was applied under constant preload (0.18 N) to pre-compress subcutaneous tissues and exert a brief (15 ms) mechanical tap at a predetermined force (0.4 N), followed by a quick release, thereby causing dampened oscillations that are recorded by the testing probe.[1] The non-neural tone or tension was calculated from the signal spectrum Fmax [fast Fourier transform (FFT)] and had the frequency (Hz) of the dampened oscillations. Stiffness (N/m) was characterized by the muscle's ability to resist an external force that modified its shape (Pisano et al., 2000). Elasticity was measured by the logarithmic decrement (log) of the dampened oscillations (dissipation of mechanical energy during one oscillation cycle), thus reflecting the ability of the tissue to recover its shape after being deformed (Mullix et al., 2012).

2.4.2. Muscle stiffness measurements

2.4.2.1. Field experiments

The first muscle stiffness sample was collected on the day before the marathon. The quadriceps muscle of the thigh and the triceps muscle of the calf were measured. All measurements were performed in a designated room. Rigidity measurements were taken at rest the day before the marathon. Subsequent measurements were made 1–2 h before the start and just after the end of the marathon run. All tests were performed by the same trained person to operate the MYOTON device.

The participants were prone on their backs or their stomachs on a unique bed, and they rested for 10 min before muscle stiffness measurements were taken. Testing sites on each muscle were located using a tape measure and marked using a skin-safe pen (Figure 1). A pillow was placed under the head, and a unique roller pillow was placed under the lower leg to aid relaxation. One series of three single Myoton measurements of each muscle group (12 points) were measured separately for the left and right legs. In addition, for a better understanding of the problem, the functionality of the lower limb was also determined - the dominant and non-dominant leg. The dominant leg for a particular runner was determined based on the information provided by the marathoner in the questionnaire.

The reliability between trials (within session) of the one selected muscles (two series of 10 single measurements) of each group was tested using intraclass correlation coefficient (ICC) model. Domholdt (1993) classification scales for interpreting ICCs was used: very high =1.00–0.90; high = 0.89–0.70; moderate = 0.69–0.50; low = 0.49–0.26. This indicated that Rectus femoris reach (ICC = 0.82) and Gastrocnemius (ICC = 0.85). The high reliability coefficient indicated that applied tests represent consistent measurement of muscle stiffness data among the runners.

2.4.2.2. Resting recordings

The second sample was collected immediately after the marathon run. All measurements were performed in a tent near the marathon finish line. Testing sites on each muscle belly were identified using a tape measure and marked using a skin-safe pen. A pillow was placed under the head, and a unique roller pillow was placed under the lower leg to aid relaxation. Again, a series of three single Myoton measurements of each muscle group (12 points) was taken separately for the left and right legs.

2.4.3. Maximal oxygen consumption measurement

All subjects underwent a maximal cardiopulmonary exercise test on a motorized treadmill (Trackmaster TMX425, Full Vision, Inc., KS, United States). After a 5-min running at 8 km/h (warm-up), the protocol started, and the treadmill speed was increased by 1 km/h every 2 min, in a stepwise fashion. The treadmill inclination was kept constant at 1°. The protocol was continued until exhaustion. Oxygen uptake (VO2, mL/min/kg) and instantaneous minute ventilation (VE, L/min) were measured breath by breath (Cosmed Quark CPET, Rome, Italy) and averaged every 30s. The highest values of VO2 and VE were taken as VO2max (mL/kg/min) and maximal minute ventilation (VEmax, l/min), respectively.

2.5. Statistical analysis

Data were tested for normality using the Shapiro–Wilk test and homogeneity of variance (Levene's test). Descriptive statistics included the mean, SD, and SE. To compare the mean values of the examined variables, repeated measures of one-way ANOVA were used. The independent variable is the time needed to complete the marathon run, whereas the dependent variables were muscle stiffness (MFT, MBS, and HR). After a significant main or interaction effect was established, the data were evaluated with a post-hoc Fisher's LSD test. The level of statistical significance was set at $p = 0.05$. Additionally,

1 http://www.myoton.com/en/Technology/Technical-specification

10.3389/fpsyg.2023.1069774

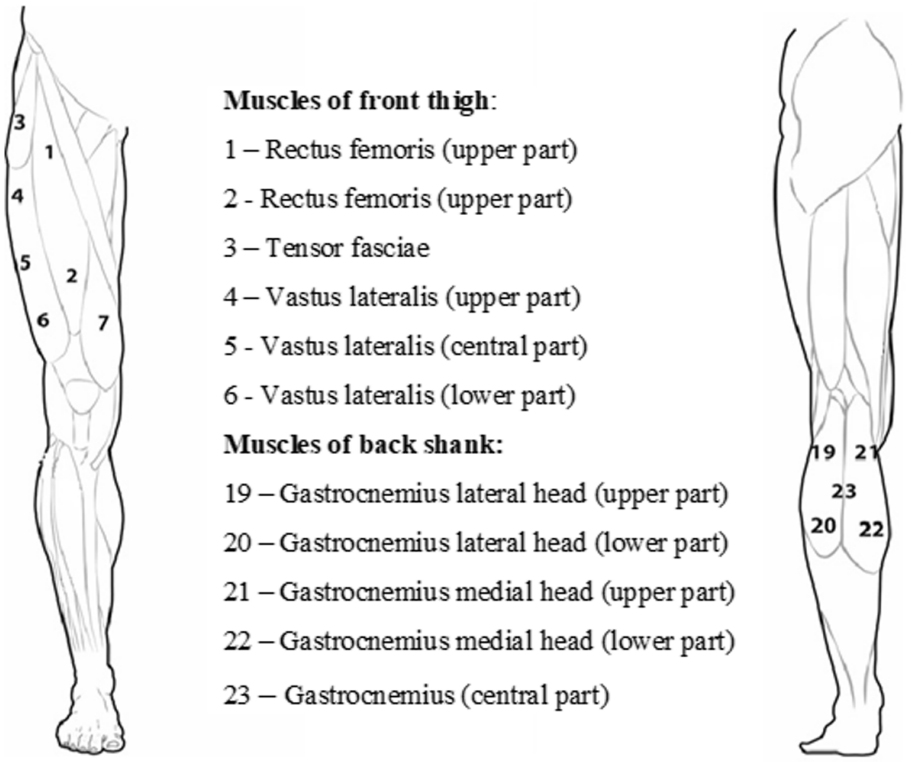

FIGURE 1
Arrangement of the measurement points of the quadriceps muscle of the thigh and the triceps muscle of the calf.

TABLE 1 Baseline characteristics of the participants, presented as mean±SD.

Variables	Mean±SD
Age (years)	57.32 ± 6.25
Body weight (kg)	75.36 ± 7.89
Height (cm)	175.61 ± 5.74
Body mass index (kg/m^2)	24.44 ± 2.32
Training experience	10.61 ± 8.81
HR max	169 ± 15.71
VO_2max (mL/min/kg)	44.51 ± 3.63
VO_2 VT1 (mL/min/kg)	33.93 ± 4.28
fR-breaths/min (VT1)	35.81 ± 6.16
VE (VT1) L/min	76.95 ± 15.32
HR (VT1)	142.10 ± 17.89
VO2 VT2 (mL/min/kg)	40.64 ± 4.28
fR-breaths/min (VT2)	45.20 ± 5.75
VE (VT2) L/min	110.12 ± 17.55
HR (VT2)	161.50 ± 16.19

Cohen's *d* was calculated, and the effect sizes were determined: 0.35 for small effect size, 0.35 and 0.65 for medium effect size, and 0.65 for large effect size (Cohen, 1988). The relationship between the variables was determined using Pearson's product–moment correlation. Statistical power was set to be >0.90 at $p = 0.05$. All statistical analyses were made using the STATISTICA ver. 13.1 (StatSoft. Inc., United States) software package.

Reliability between trials (within-session) for one of the selected muscles (two series of 10 single measurements) of each group was tested using the intraclass correlation coefficient (ICC) model. Domholdt classification scales (Carter et al., 2011) for interpreting ICCs were used: very high = 1.00–0.90; high = 0.89–0.70; moderate = 0.69–0.50; and low = 0.49–0.26. ICCs were found for the rectus femoris (ICC, 0.82), biceps femoris (ICC, 0.86), tibialis anterior (ICC, 0.91), and gastrocnemius (ICC, 0.85). The high reliability of the coefficients indicated that the tests resulted in inconsistent measurements of muscle stiffness among the Marathon runners.

3. Results

The 42.195-km run was completed in 4.30,05 h ± 35.12, which indicates an intensity of 79.3% ± 7.1% of HRmax. The average body height of the marathon runners was 175.61 ± 5.74 cm, their body weight was 76.17 ± 7.73 kg, and their BMI was 24.44 ± 2.32. A low level of HRmax and VO2max was visible. Similar relationships can be seen in the case of VO2 at the aerobic threshold (VT1) and anaerobic threshold (VT2). The participant's percentage of the Wrocław Marathon on VT1 achieved 76.23% VO2max. The possibilities at the VT2 hall were 91.3 and 84.65% HRmax (Table 1).

Figure 2 shows the speed variability with the division into individual sections (every 5 km) and the average HR on these sections. It can be seen that the beginning of the drop in speed starts at 12 km

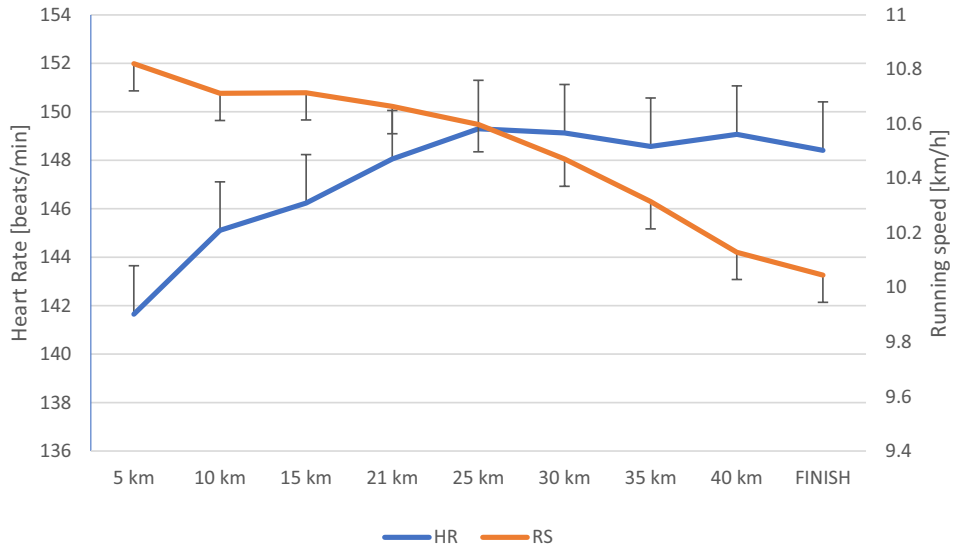

FIGURE 2
Changes in heart rate [beats/min] and running speed [km/h] during the marathon (mean±SD).

TABLE 2 Differences in muscle stiffness before and after the marathon (mean±SD).

Leg	Muscle group	Before marathon	After marathon	*F*	*p*	Cohen's *d*
Left	Calf	302.88 ± 33.14	292.10 ± 22.88	6.534	0.016	0.38
	Quadriceps	310.43 ± 29.46	301.92 ± 38.00	2.393	0.132	0.25
Right	Calf	313.19 ± 41.86	303.39 ± 28.29	3.493	0.071	0.28
	Quadriceps	294.94 ± 20.54	297.94 ± 25.59	0.876	0.357	0.13

and continues to the end of the run. Along with the decrease in rate, there was a gradual increase in HRmax, which lasted until the marathon's end.

The analysis of muscle stiffness levels in relation to their subsequent measurements (before and after the marathon) revealed that a significant effect was observed only for the left calf ($F = 6.534(1)$; $p = 0.016$; medium effect size). No significant effect was found for the left quadriceps ($F = 2.393(1)$; $p = 0.132$), the right calf ($F = 3.493(1)$; $p = 0.071$), or the right quadriceps ($F = 0.876(1)$; $p = 0.357$; Table 2).

The Spearman's rank correlation analysis did not reveal any significant correlation between running speed or HR level, measured over the entire distance divided into 5 km sections, and muscle stiffness of the quadriceps and triceps calf muscles. On the other hand, significant relationships occurred only between the VO2max measurement (measured before the race) and the speed at each of the 5-km sections of the marathon distance and the finish ($p = 0.000034$ and $p = 0.000239$, respectively).

4. Discussion

This research examines the relationship between marathon performance and changes in muscle stiffness from pre to marathon in middle-aged recreational marathon runners. The hypothesis regarding muscle stiffness was not supported, as the current investigation revealed significantly lower levels of stiffness post-marathon for the calf muscles in the left leg ($p = 0.016$). No significant changes were noted in muscle stiffness at the post-marathon assessment in the other two tested muscle groups (quadriceps, left and right lower limbs, and calf in the right stem).

The explanation of this phenomenon is likely to be difficult because none of the previously described studies have documented the impact of a prolonged running effort, commonly defined as a marathon, on muscle stiffness. Additionally, this requires the consideration of indirect analyses of other variables which affect the marathon effort. This approach is also considered difficult because many of the factors to be analyzed were not included in this experiment. This is because many of these variables are difficult to measure without interfering with the running autonomy. However, it has been well described how long-distance running directly impacts the running economy (RE) (Quinn et al., 2011). It seems reasonable to combine all these factors, due to the non-exclusive relationships, to optimally assess the marathon effort and its direct impact on changes in the runner's body after such a long effort. Knowing this may help runners improve their marathon performance and develop an appropriate training program, optimally preparing them to run 42.195 m, regardless of their championship, intermediate, or recreational level. An essential element of such an analysis is the division into sex, mainly into age categories, with a particular emphasis on 50+ (Beck et al., 2016).

It is well known that marathon performance depends on the running economy (RE) in all the world's weariness. RE is an 'aerobic demand' to maintain a reasonable pace: speed over distance. It is defined as the stationary oxygen uptake (VO2) associated with this

speed (Sproule, 1998; Kyröläinen et al., 2000). Comparing our participants with younger marathon runners aged 43.9 ± 8.3, the values of HRmax were lower by an average of 9.2 (bpm) and 4.29 (mL/min/kg; Nikolaidis and Knechtle, 2018). More significant differences occur compared to the group of recreational runners (63 ± 32 km/week) aged 34 ± 8 years. The differences in HRmax and VO2max are 14.5 (bpm) and VO2max by 18.69 (mL/min/kg), respectively, favoring the younger runners (Lanferdini et al., 2020). Similar relationships can be seen in the case of VO2 at the aerobic threshold (VT1) and anaerobic threshold (VT2). Younger runners are characterized by higher VO2 at these thresholds (3.67 for VT1 and 12.86 for VT2; Lanferdini et al., 2020). Despite the lower values of these indicators, the marathon runners studied in Wrocław consumed more oxygen about their abilities than younger recreational athletes. The percentage of participants of the Wrocław Marathon on VT1 achieved 76.23% VO2max, while the competitors studied by Lanferdini et al. (2020) only 59.49% VO2max. Comparing the capabilities at the VT2 threshold, the results were 91.3 and 84.65% HRmax, respectively. Despite this, our marathon runners showed a strong relationship between Vo2 max and speed on each subsequent 5-km section (from 0.000034 to 0.000239). This previous confirmed research found a strong relationship between VO2 max and the level of effort in a marathon run.

It is also evident that the RE must be associated with the marathon runner's running technique and that this, in turn, depends on the resistance of the runner's body to fatigue and falling running speed. In our experiment, marathon runners began to experience a drop in running speed after 12 km of a race. A continuous, slow decrease in rate started from that moment on, which amounted to approximate 5.6% at the finish line. This did not confirm the reports of Hettinga et al. (2019) that during the late stages of the marathon (the last 10–15 km), a considerable deceleration usually occurs. This affects even world-class runners and is recognized by runners as 'hitting the wall' (Buman et al., 2009). This is probably because our runners are classified as slow, recreational runners, over 50 years of age, so their marathon effort can be defined as prolonged (4.30,05 h ± 35.12 min.) but of low intensity.

On the other hand, world-class marathon runners have developed training strategies to manage or prevent fatigue and sharp drops in running speed (Hanley et al., 2020). The studies by Buckalew et al. (1985) and Chan-Roper et al. (2012) regarding the effects of fatigue on running technique showed that technique changed by decreases in step length rather than step frequency. These changes were directly responsible for the decreased speed. Marathon runners are predominantly rear-foot strikers, valid for world-class (Hanley et al., 2019) and recreational long-distance runners (Larson et al., 2011). This can be applied to our marathon runners with an indication of the activity of the left leg and with particular emphasis on the triceps muscle of the calf. They noticed a few disadvantages in this matter. A significant potential biomechanical limitation of landing with a rear-foot strike pattern is that the foot lands in front of the whole body's center of mass. This increases the braking force and directly impacts the speed, mainly reducing it by the resulting weaker take-off. This negatively influences the step length by shortening it. The second disadvantage of the running technique when fatigue appears is that landing almost the whole foot on the ground during the early stance and continuing during the main amortization phase significantly increases contact time. In turn, the high center of mass is achieved through knee flexion. The greater the knee flexion, the longer the foot–ground contact time, and the higher the speed reduction. Additionally, according to Derrick et al. (2002), fatigue may decrease the utilization of the stretch-shortening mechanism, especially in the hip and knee joints. This causes the knee flexors and extensors to tire more quickly, which results in reduced leg stiffness. Despite this assumption, the relationship between running speed on each 5-km stretch (increasing fatigue with each km) and muscle stiffness was not confirmed with no change in muscle stiffness. However, a much more significant correlation was found for the triceps muscle of the calf (mean significance level: $p = 0.354612$). This can be confirmed because this muscle has a more significant functional impact on the running step technique. It weakens the ground reaction forces, thus significantly extending the contact time (Mercer et al., 2002). These elements mean a considerable speed reduction, and the runners thus achieve poor results. In addition, these undesirable factors should be eliminated in training to achieve optimal results in the marathon about motor preparation. At the same time, these parameters, which should not weaken the running technique, had a positive effect on muscle stiffness. This did not change after the marathon effort compared to the measurements before the race.

Changes in the mechanical properties of the muscles observed after prolonged physical activity may be associated with increased joint stiffness. In terms of performance, the increased stiffness was associated with increased speed, increased jump velocity, jump height, and running economy (measured by oxygen consumption; Sadeghi et al., 2018). According to Beckett et al. (2017), followed by Kerdok et al. (2002), a critical determinant of running economy is the spring-like storage and return of elastic energy from the leg during a stance. Here we have to distinguish between muscle stiffness and joint stiffness, often equated with leg spring stiffness. The latter measures the stiffness of the muscle and tendon, but regarding how well a runner can recoil the elastic energy generated during ground contact in each stride. Therefore, increased joint stiffness, mainly by eccentric contraction movement, shorten ground contact (Kerdok et al., 2002; Bus, 2003) and generate more elastic energy. This indicates an improvement in running economy over time and an increase in delayed-onset muscle soreness.

According to Beckett et al. (2017), it can be concluded that the assessment of older runners may be indirectly based on leg stiffness, through reduced tendon stiffness (Karamanidis et al., 2005; Magnusson et al., 2008), lower active peak ground vertical reaction forces (GRF) (Bus, 2003), and greater flexion at the knee joint at landing (Fukuchi and Duarte, 2008; Kulmala et al., 2014). This suggests that leg spring stiffness decreases with age (Beck et al., 2016). Did this occur in our marathon runners?

One of the limitations of this study is the absence of subsequent measurements of muscle stiffness, e.g., 12 h or 24 h after completing the marathon. This was not due to the technical feasibility of the measures but to the personal reasons of the competitors. Such measurements would have also allowed us to observe DOMS changes about the delayed changes. Another limitation is the lack of a running technique evaluation on video recording, e.g., 15 km or 40 km into the race. This would have allowed us to correctly describe the marathoners' running technique and juxtapose it with VO2 to evaluate their running economy.

5. Conclusion

The long-term, low-intensity running effort (marathon) in older recreational runners, along with a low HRmax and VO2max, showed no statistically significant changes in muscle stiffness (quadriceps and calf muscles). There was, however, reduced muscle stiffness, but only in the triceps calf of the dominant (left) leg. Additionally, when we consider the failure to keep an optimal running economy, expressed as a technical disorder (shortened running step, increased ground contact time, lowering the legs in the knee joint) and increasing fatigue, we can surmise why muscle stiffness did not change post-exercise. Therefore, this experiment did not confirm the hypothesis that mechanical muscle properties and resting tone may change after prolonged exercise.

From a practical point of view, the lack of changes in muscle stiffness in the post-marathon suggests that the training of the marathon mentioned above runners are based on too low intensities. It is closely related to the results they achieved in the experiment. Therefore, the improvement of the development in the marathon, especially in the advanced age of marathon runners, will occur by increasing the running training with greater intensity. This will allow the runner to experience increased muscle stiffness during training. Then transfer it to the competition.

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 local Institutional Ethics Committee (Senacka Komisja ds. Badań Naukowych przy Akademii Wychowania Fizycznego we Wrocławiu). The patients/participants provided their written informed consent to participate in this study.

Author contributions

KM, JC, DM, DP, and PP conceived and designed the experiments. KM, JC, DM, DP, PC, and MK performed the experiments. KM, JC, DM, DP, PC, and MK analyzed the data. BeP, RS, MW, AN-C, WŁ, DA, SW, PP, and BaP interpreted the results. KM and DM drafted and edited manuscript. All authors critically revised paper and approved the final version of the manuscript. All authors contributed to the article and approved the submitted version.

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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

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Asymmetry of the pelvis in Polish young adults

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Introduction: Symmetry is one of the criteria of correct body posture in upright position. The spatial positioning of the pelvic girdle is crucial to it. Functional and structural asymmetries within the lumbo-pelvic-hip complex can have a significant influence on the structure and functions of many human body organs and systems. The aim of the study was to present the results of inclinometer measurements of selected landmarks of the pelvic girdle in young adults aged 19–29.

Methods: The analysis of occurrence of spatial pelvic asymmetry was based on the authors' original, clinical classification and the significance of the body mass and height for the analyzed asymmetries. The inclinometer measurements of the selected landmarks of the pelvic girdle were performed in a sample consisting of 300 young individuals. Then, the occurrences of the spatial asymmetry of the pelvis were analyzed based on the authors' own clinical classification using alignment symmetry of the iliac crests, the anterior superior iliac spines and the trochanters major as a criterion. All study subjects with asymmetry <1 degree were treated as those with a symmetrical pelvis.

Results: The significance of gender, body mass and height for the analyzed asymmetries was assessed. Symmetric positioning of the iliac crests was observed in only 32% of the respondents. The iliac crest depression on the left side was more frequently observed – in 41% of the respondents. This occurred more often in women (44%) than in men (38%). In the group of women, the rotated pelvis was the most often observed (39.4%) asymmetry, while for men, it was the oblique pelvis (40%). More detailed analysis by pelvic asymmetry subtypes showed their statistical differentiation between women and men ($p<0.0001$). Analysis of moderate rotation of the pelvis for men, were reported slightly higher values but these differences were not statistically significant ($p=0.253$). Women, in turn, showed slightly higher mean values but here too, the differences were not statistically significant ($p=0.245$).

Discussion: Asymmetries in the pelvis area are common; they were observed in less than three-quarters of the examined population. Oblique pelvis was found in less than a quarter of women and in more than one-third men with the predominant structural asymmetries. Rotated pelvis was observed in more than one-third of women and men with dominating functional asymmetries. There were no linear correlations between the body mass and height, and the angle of asymmetries.

KEYWORDS

diagnostics, human body, physiotherapy, pelvic girdle, postural asymmetry factor

Introduction

Symmetry is one of the criteria of correct body posture in upright position. Human posture in the frontal and transverse plane should show a symmetric positioning of the pelvis, straight spine and symmetric alignment of the selected landmarks in the torso area. However, it is known that in reality, this happens extremely rarely. There are many signs of asymmetry. From functional asymmetries resulting, for example, from the lateralization process, performing asymmetric movements, changes of the functional condition of muscles, tendons and joint capsules, to static asymmetries which occur in response to developmental disorders or diseases. Spatial position of the pelvic girdle is crucial for the development of correct body posture (Applebaum et al., 2021). Pelvis is an important structure which connects the torso and the lower limbs to support and transfer the load on to the legs during different functional movements. It is a part of the lower torso in the sitting position but during standing or walking, it becomes a functional element of a lower limb (Murray et al., 2017; Dubey et al., 2018).

That is why changes in pelvis position when standing affect also balance and functionality (Gurney, 2002; Verheyden et al., 2006; Khamis and Carmeli, 2017; Murray et al., 2017) In addition, control of pelvis alignment is necessary to produce more efficient movements and walking (Gurney, 2002; Staszkiewicz et al., 2012), and if it is not controlled properly during walking, the speed, stability and efficiency of the walk decreases (Dickstein and Abulaffio, 2000; Gurney, 2002; Chen et al., 2003). It is assumed that pelvis should be positioned symmetrically. However, asymmetries in its area are often observed. It is related to the anatomy as such, different bone anomalies (e.g., hip dysplasia; Li et al., 2016; Wells et al., 2017), degenerative or inflammatory processes, fractures or injuries of the pelvis (Garvey and Hazard, 2014; Tile et al., 2015; Rommens and Hofmann, 2017; Stover et al., 2017). Pelvic asymmetries most often mentioned in clinical practice include asymmetries in the frontal plane (pelvic obliquity) associated with actual or functional leg length inequality (Brady et al., 2003; Applebaum et al., 2021), asymmetries in the transverse plane (rotated pelvic), or mixed forms (Juhl et al., 2004; Al-Eisa et al., 2006; Gnat and Bialy, 2015). Asymmetries of the pelvis can be associated with the development of non-specific chronic low back pain, caused by incorrect mechanical load on the body which increases the stress on the soft tissues in the lumbar section (Brady et al., 2003; Sorensen et al., 2016; Azizan et al., 2018; Applebaum et al., 2021). They can also contribute to the development of functional scolioses (Ploumis et al., 2018; Kobayashi et al., 2020) or degenerative changes of joints (Harvey et al., 2010). Assessment of pelvic asymmetry can be useful in anatomic examinations, functional behavior analysis, mobility assessment, biomechanical explorations, development of implants and other clinical applications (Tobolsky et al., 2016; Osterhoff et al., 2019).

It seems, however, that despite so much attention paid to these issues, there are no clinical methods which would provide the base for more advanced diagnostics and support therapeutic decisions. At present, the most information refers to radiologic examinations of the pelvic girdle. Based on them, diagnostic schemes and therapy recommendations are developed. They are reliable, repetitive and accurate (Lee et al., 2015; Kurki, 2017; Handrich et al., 2021; Zhang et al., 2022a). Parallel to the radiologic examinations, methods based on palpation of the selected landmarks in the pelvic girdle area are used. Unlike radiology, they are less reliable and show great randomness (Stovall and Kumar, 2010; Kilby et al., 2012; Li et al., 2016; Mine et al., 2022). The result of a search for methods which would be at least partially as reliable as radiologic methods, are assessments using three-plane image analysis systems (Furian et al., 2013; Yu et al., 2020) or simple measuring devices like Palpation Meter or Duometer (Levangie, 1999; Petrone et al., 2003; Bibrowicz and Bibrowicz, 2011a, 2011b).

Up to date, to the best of our knowledge, there are no scientific reports clearly describing pelvic asymmetry in young adults. That is why the aim of the study was to present the results of inclinometer measurements of selected landmarks in the lumbo-pelvic-hip complex in young adults aged 19–29. The analysis of occurrence of spatial pelvic asymmetry was based on the authors' original, clinical classification and the significance of the body mass and height for the analyzed asymmetries.

Materials and methods

Study design

This is an observational (cross-sectional) study. The study protocol follows the guidelines of the Helsinki Declaration. This study was conducted in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies (von Elm et al., 2008). It was part of the research program "Assessment of position and functional mobility of lumbo-pelvic-hip complex and their influence on the quality of body posture, postural stability and locomotion in population of children, adolescents and adults." The program was approved by the Bioethics Board of the Higher School of Physiotherapy in Wroclaw, approval No. 1/2010 of 10.04.2010, and was carried out in the Body Posture Scientific and Research Center in the College of Education and Therapy in Poznan. Each time, examinations were based on written consent provided by the participants.

Setting

Examinations were carried out in 2016–2020 among the students of Kazimiera Milanowska College of Education and Therapy in Poznan and the Silesian University of Technology in Gliwice.

Participants

The sample consisted of 300 young adults aged 19–29 years (150 women X = 21.4, SD = 3.18 and 150 men X = 21.2, SD = 3.52), selected by means of simple random sampling. They were the representative group recruited from the population of 2,131 individuals (1,321 women, 810 men).

The inclusion criteria were as follows:

- Age between 19 and 29 years;
- no visible locomotor system dysfunctions (lack of clearly confirmed health issue);
- lateralization—in order to unify the sample, only individuals with right-sided lateralization in the area of upper and lower limbs were recruited for further examinations;

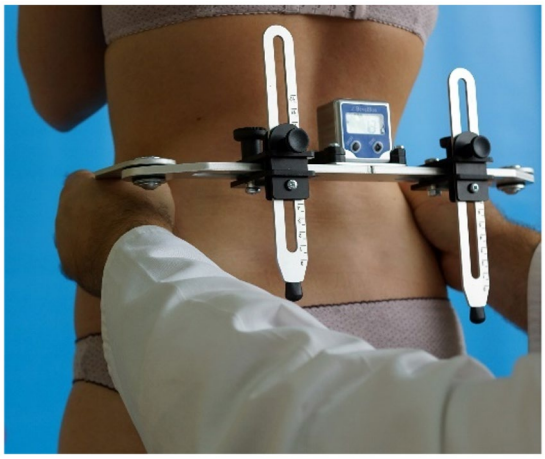

FIGURE 1
Measurement of iliac crest angle using Duometer (own source).

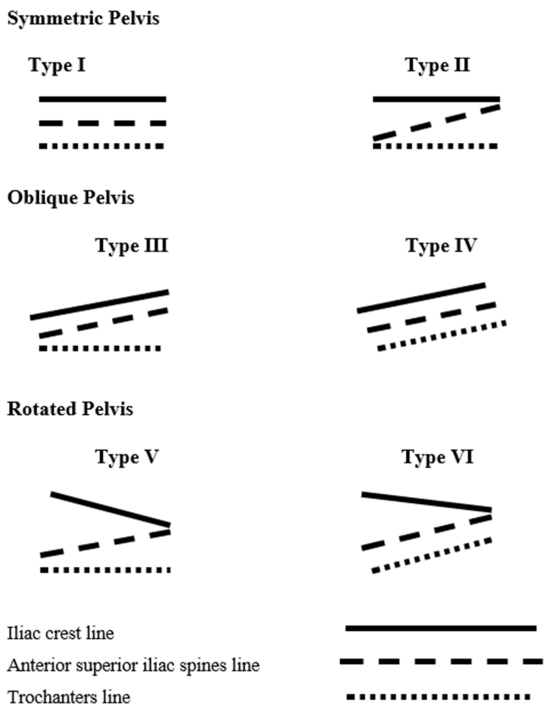

FIGURE 2
Graphic representation of pelvic asymmetry types (own source).

- correct body mass according to Body Mass Index (BMI).

The exclusion criteria were:

- Syndromes related to the Central Nervous System (CNS) and/or locomotor system, hindering correct psychomotor development;
- disorders which potentially cause postural pathologies: genetic syndromes, hormonal disorders, neuromuscular diseases, congenial locomotor system defects;
- undermass, overmass, and obesity;
- lack of written consent to take part in the study.

Outcome measures

- Mass and height measurement (using a verified medical column scale C315.60/150.OW-3—a 100–200 cm height measuring device UNIWAG—Professional electronic scales, Krakow, Poland);
- Determination of obesity using the BMI;
- Measurement of the position of the selected landmarks in the pelvic girdle using scalable anthropometric leveler with electronic inclinometer—Duometer (Figure 1):

o ICA—iliac crest angle—the angle between the horizontal axis and the line formed by the apices of the iliac crests;
o ASISA—anterior superior iliac spine angle—the angle between the horizontal axis and the line formed by the anterior superior iliac spines;
o TMA—trochanter major angle—the angle between the horizontal axis and the line formed by the tops of the greater trochanters.

Intervention

All the examinations were performed in the morning, to ensure the uniform measurement conditions. Every individual was tested three times and the averaged data were protocoled. All the measurements were performed by the same, experienced investigator. During each examination, the rule was followed that the examined landmark was touched with the tip of the middle finger and the measuring device arms were positioned strictly on the radial side of the middle finger. The material collected was divided into groups according to the spatial location of the selected landmarks on the pelvic girdle, using the author's original clinical typology (Figure 2).

The proposed clinical pelvic symmetry classification (Preece et al., 2008) is based on the analysis of mutual position of lines running through the selected landmarks of the lumbo-pelvic-hip complex:

1. the line connecting the tops of the iliac crests—IC
2. the line connecting the anterior superior iliac spines—ASIS
3. the line connecting the tops of trochanter major of the femur—TM

The measurement was carried out with an accuracy of 1°.

The proposed classification by the symmetry of positioning of the selected landmarks in the pelvic girdle and lower limbs:

I. **Symmetric Pelvis (SP)**

a. Type 1—All lines run parallel to the floor.
b. Type 2—The iliac crest line and the trochanter major line run parallel to the floor, the position of the iliac spines may show small signs of asymmetry. This may be caused by individual anatomical differences (Duboc et al., 2015).

All study subjects with asymmetry < 1° were treated as those with a symmetrical pelvis.

II. **Oblique Pelvis (OP)**

a. Type 3—The iliac crest line and the iliac spine line run the same way, in an oblique way, the trochanter line is parallel to the floor—functionally oblique pelvis (connected with, for example, asymmetrical stress of the gluteus medius).
b. Type 4—The lines of the iliac crests, the iliac spines and the trochanters run the same, oblique way—structurally oblique pelvis (e.g., short lower limb).

III. **Rotated Pelvis (RP)**

a. Type 5—the iliac crest line and the anterior superior iliac spine line are alternatively asymmetrical. The line of the greater trochanters runs parallel to the floor—functionally rotated pelvis.
b. Type 6—the iliac crest line and the anterior superior iliac spine line are alternatively asymmetrical. The line of the greater trochanters is tilted against the floor. Most frequently in the same way as the line of the anterior superior iliac spines—structurally rotated pelvis.

Together with the quantitative characteristics of the variables, the characteristics of frequency of the occurrence of oblique and rotated pelvis, depending on the asymmetry ratio, was presented. The classification was made by means of analysis of the angle of asymmetry and determination of its intensity according to the authors' own typology:

1. The base to determine the obliquity of the pelvis was the inclination angle of the line of the apices of the iliac crests against the horizontal axis.
2. The pelvic rotation was determined based on the angle between the line of the apices of the iliac crests and the line of the anterior superior iliac spines.

It was assumed that:

1. Slight asymmetry $\geq 1^{o} \leq 3{,}0^{o}$ (percentile < 25).
2. Moderate asymmetry $> 3^{o} \leq 6^{o}$ (percentile 25–75).
3. Significant asymmetry $>6^{o}$ (percentile > 75).

Data analysis

The minimum size of the sample was determined based on the formula:

$$\mathrm{Nmin} = \mathrm{NP}\left(\pm 2{\cdot}\mathrm{f}\left(1-\mathrm{f}\right)\right)\mathrm{NP}{\cdot}\mathrm{e}2 + \pm 2{\cdot}\mathrm{f}\left(1-\mathrm{f}\right)\mathrm{Nmin}$$
$$= \mathrm{NP}\left(\pm 2{\cdot}\mathrm{f}\left(1-\mathrm{f}\right)\right)\mathrm{NP}{\cdot}\mathrm{e}2 + \pm 2{\cdot}\mathrm{f}\left(1-\mathrm{f}\right)$$

where Nmin, minimum sample size; NPNP, population from which the sample is selected $n = 2{,}131$, α—level of confidence for the results = 95%, f—fraction size = 0.5 e—maximum error assumed 5% = 0.05 (Zalewska and Niemiro, 2022).

The statistical analysis of the material was conducted using MedCalc ver.20.104 package. Distributions of the variables were determined by means of Shapiro–Wilk test. The results were presented as average and standard deviation completed with the median. The analysis of differences was performed using nonparametric tests (Mann–Whitney *U*-test). To analyze the qualitative variables, Chi-squared test was used. Relationships between the variables were investigated using Spearman's rank correlation tests.

Results

The sample consisted of 300 individuals (150 women and 150 men) aged 19–29 years. Table 1 presents the detailed anthropometric data of the sample. Figure 3 shows the qualification stage.

Position of selected landmarks of the pelvic girdle and lower limbs

The analysis of symmetry between the examined landmarks shows significant differentiation depending on the gender. At the same time, individual results are clearly and significantly dispersed (Table 2; ICA $p = 0.029$; ASISA $p = 0.020$, TMA $p < 0.001$). The symmetry analysis which takes into account their direction also shows significant gender-related differences. Symmetric positioning of the iliac crests was observed in only 32% of the respondents ($p = 0.001$). The iliac crest depression on the left side was more frequently observed – in 41% of the respondents. This occurred more often in women (44%) than in men (38%). The iliac crest depression on the right side was observed in only 18% of women and as much as 36% of men (Table 3). The opposite situation was observed in terms of direction of the anterior superior iliac spine asymmetry ($p = 0.028$). The left spine was lowered in only 10% of women and men, whereas lowered right iliac spine was diagnosed in 57.7% of women and as much as 70% of men (Table 3). Symmetrical position of the spines was observed in only 33.3% of female and 20% of male respondents (Table 3). Symmetrical position of the trochanters (equal length of the lower limbs) was observed in 81.3% of women and 56% of men ($p \leq 0.000$). Trochanter depression on the right side was observed in 14% of women and as much as 36.7% of men (Table 3).

Frequency of occurrence of identified types of pelvic girdle asymmetries in young adults

The analysis of the occurrence of the certain types of pelvis shows significant differences between women and men (OP $p = 0.010$; SP $p = 0.014$; Table 4). In the group of women, the rotated pelvis was the most often observed (39.4%) asymmetry, while for men, it was the oblique pelvis (40%). Symmetric positioning of the pelvis was observed in only 22% of the respondents. It was more frequent among women (37.3%). More detailed analysis by pelvic asymmetry subtypes

TABLE 1 Research group.

Sex variable	Women n=150	Men n=150
	Mean±Std.	Mean±Std.
Weight [kg]	61.5 ± 8.71	78 ± 10.69
Height [cm]	166 ± 5.99	18 ± 7.81
BMI [kgm^{-2}]	21.6 ± 2.04	22.7 ± 1.35

n, number of participants; Std, standard deviation.

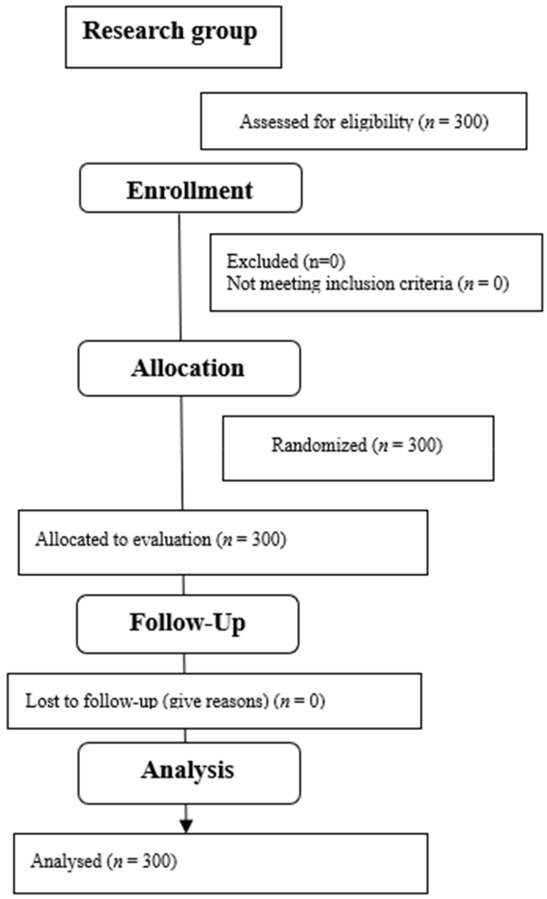

FIGURE 3
Flow diagram.

showed their statistical differentiation between women and men ($p < 0.0001$*). The dominating type in the symmetric pelvis group was Type 1 (Table 4). In the oblique pelvis group, Type 4 (structural) was predominant. In the rotated pelvis group, it was Type 5 (functional) with the greater trochanter tops located at the same level (Table 5).

Quantitative and qualitative assessment of angle of obliquity and rotation of pelvis in examined groups

The analysis of moderate rotation of the pelvis, measured as the angle between the line running through the tops of the IC and the ASIS, indicated that the variable distribution is different for women and for men (Figure 4). As for men, slightly higher values were reported but these differences were not statistically significant ($p = 0.253$). The opposite situation was identified during the analysis of the angle of the pelvic obliquity (Figure 5). Women, in turn, showed slightly higher mean values but here too, the differences were not statistically significant ($p = 0.245$). The analysis of frequency and angle of pelvic asymmetries did not reveal any significant differences between male and female respondents (oblique pelvises $p = 0.309$, rotated pelvises $p = 0.594$). However, it was noticed that in the case of oblique pelvises, slight asymmetries dominated in both groups, whereas in the rotated pelvis group—moderate and significant asymmetries were predominant (Figure 6).

Assessment of correlations between variables

The analysis of correlations between the body mass and height and the asymmetry angle of the iliac crests, the anterior superior iliac spines and the greater trochanters, conducted using Spearman's correlation coefficient, did not show linear correlations between the investigated parameters. Minor correlations between the body mass and the angle of trochanter major asymmetry were considered accidental (Table 6).

Discussion

The aim of the study was to present the results of inclinometer measurements of selected landmarks in the lumbo-pelvic-hip complex in young adults aged 19–29. The analysis of occurrence of spatial pelvic asymmetry was based on the authors' original, clinical classification and the significance of the body mass and height for the analyzed asymmetries. The analysis of positions of the selected landmarks of the pelvic girdle shows frequent occurrence of asymmetries. The iliac crest asymmetry was observed in 68% of the respondents, women slightly more often than men. The iliac crest depression on the left side was more frequently observed, similar in both groups. Greater differences occurred in the lowering of the iliac crest on the right side. Greater asymmetry was found in men. Such a high percentage of iliac crest asymmetry confirms the previous observations of the authors as well as other researchers (Brady et al., 2003; Kurki, 2017; Mundorf et al., 2021; Zhang et al., 2022a). ASIS asymmetries were observed equally often. Contrary to the iliac crests which were more often lowered on the left side, the iliac spines were more frequently lowered on the right side. The results of the analysis of trochanter major tops symmetry were very different. More symmetrical alignment was observed in women. According to the authors, this may indicate a significant percentage of functional

TABLE 2 Size of iliac crest angle (ICA), anterior superior iliac spine angle (ASISA), and trochanter major angle (TMA) by gender.

Sex variable	Women n=150	Men n=150	p
	Mean±Std. (median)	Mean±Std. (median)	
ICA (°)	1.6 ± 1.72 (1.0)	2.0 ± 1.75 (2.0)	0.029*
ASISA (°)	1.8 ± 1.7 (2.0)	2.3 ± 1.72 (2.0)	0.020*
TMA (°)	0.5 ± 1.15 (0.0)	1.2 ± 1.62 (0.0)	<0.001*

ICA, iliac crest angle; ASISA, anterior superior iliac spine angle; TMA, trochanter major angle; p, p-value (Mann–Whitney test); *, statistically significant differences; n, number of participants.

TABLE 3 Direction of asymmetry of IC, ASIS, and TM tops position by gender.

Sex Variable	Women *n*=150						Men *n*=150						*p*-value test
	Left ↓		Symmetric		Right ↓		Left ↓		Symmetric		Right ↓		
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	
IC	66	44	57	38,4	27	18	57	38	39	26	54	36	0.001*
ASIS	15	10	50	33.3	85	57.7	15	10	30	20	105	70	0.028*
TM	7	4.7	122	81.3	21	14	11	7.3	8	56	55	36,7	<0.000*

IC, top of iliac crest; ASIS, top of anterior superior iliac spine; TM, top of trochanter major; p, *p*-value (Chi^2 test); *, statistically significant differences; ↓, landmark located below; *n*, number of participants.

TABLE 4 Frequency of occurrence of pelvic girdle asymmetry types in examined groups.

Sex	Women *n*=150		Men *n*=150		Women + Men *n*=300		Women vs. Men *p*
Types of pelvic asymmetry	*N*	%	*N*	%	*N*	%	
OP	35	23.3	60	40	95	31.7	0.010*
SP	56	37.3	33	22	89	29.7	0.014*
RP	59	39.4	57	38	116	38.7	0.852
p	0.032*		0.012*				

p, *p*-value (Chi^2 test); *, statistically significant differences; OP, Oblique Pelvis; SP, Symmetric Pelvis; RP, Rotated Pelvis; *n*, number of participants.

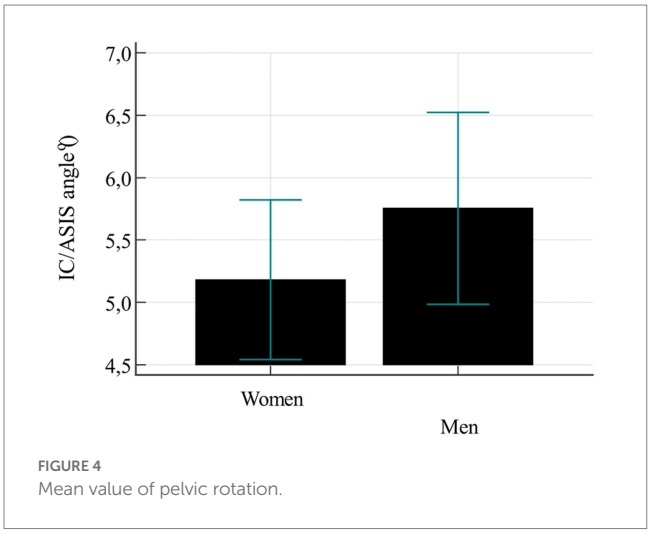

FIGURE 4
Mean value of pelvic rotation.

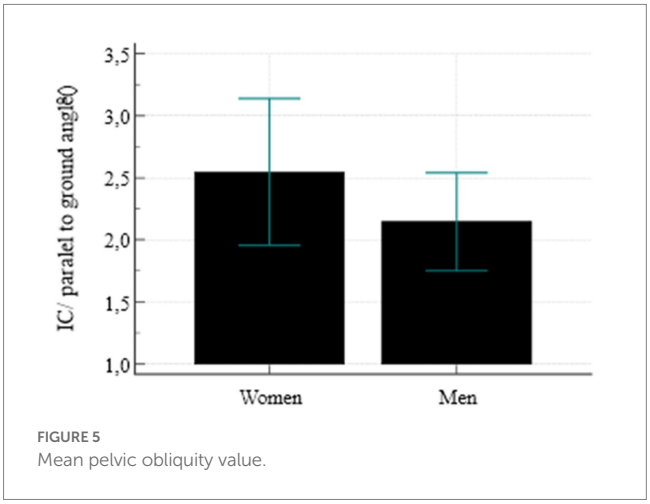

FIGURE 5
Mean pelvic obliquity value.

asymmetries or asymmetries which are not related to the limb inequality. On the other hand, bilateral differences in bone length of the upper and lower limbs are associated with different mechanical stress put on the bones during growth and are called directional asymmetry. In the upper limbs, this skeletal asymmetry is usually visible on the dominant side, while in the lower limbs—on the opposite side. This is probably due to auxiliary contractions of the opposite muscles, which affect the bone growth. This contralateral dominance in the upper and lower limbs is known as cross symmetry pattern (Alqadah et al., 2018). In the study described herein, only individuals with the right-sided dominance in the area of upper and lower limbs were examined and the connection with the crossover symmetry in the pelvic area was not clear.

Asymmetry of the pelvis exhibited as the difference in the height of the right and left hip is called pelvic obliquity or leg length inequality (Zhang et al., 2022b). According the authors, these terms are not synonyms due to different causes of the asymmetries. Not every difference in the iliac crest height results from unequal limb length. Considering only the asymmetry in the iliac crest height and making therapeutic decision based on that may affect the effectiveness of the therapy. This was taken into consideration when the pelvis asymmetry classification used in the study was developed. The analysis conducted showed that only one third of the respondents had symmetric pelvis. Also, symmetric pelvis was found significantly more often in women. Oblique pelvis was observed significantly more frequently in men. In turn, rotated pelvis was observed more often in female participants.

In the group of individuals with oblique pelvis, Type 4 (structural) of the asymmetry was definitely dominating. Among the respondents with rotated pelvis, Type 5 (functional) was predominant as compared to Type 4 (structural) where, together with the contralateral asymmetry of the iliac crests and the iliac spines, the trochanter major asymmetry was observed. There was a minor differentiation of the mean pelvic obliquity angle and rotation angle between women and

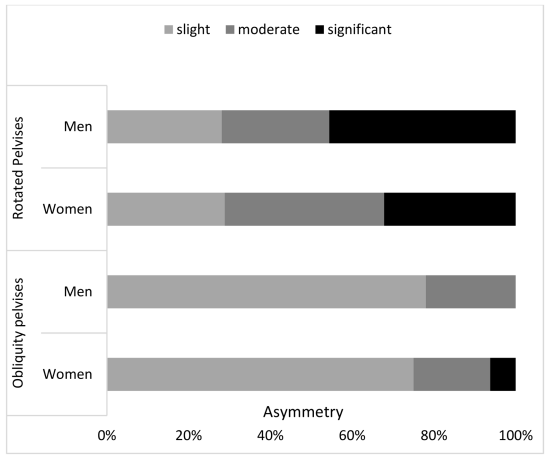

FIGURE 6
Frequency and magnitude of rotated and oblique pelvises (%).

men but the differences were not statistically significant. The qualitative analysis of the asymmetry angle showed that women and men with oblique pelvis had mainly slight asymmetries while individuals with rotated pelvis – moderate and significant asymmetries. It was concluded that anthropometric parameters had no linear correlations with the asymmetries studied.

Body asymmetry is more of a standard rather than an exception. Thus, the occurrence of different types of is are not surprising. This refers both, to structure and function. Starting from brain and central nervous system asymmetries (Kanchan et al., 2008; Medina-Rivera, 2016; Güntürkün and Ocklenburg, 2017). They can have many causes, for example optic nerve diseases (Traver-Vives et al., 2021) or differences in lateralization ontogenesis (Kanchan et al., 2008), craniofacial asymmetries (Maloney, 2019) or ontogenetic differences in the limb length (Alqadah et al., 2018; Bishop et al., 2018). The relations between the structural and functional asymmetries are also often analyzed (Brady et al., 2003; Applebaum et al., 2021). Asymmetries are also assessed in the context of athletic achievements. The sports experience of the players (Piepiora et al., 2022a), their sports level (Piepiora et al., 2021) and anthropometric predispositions (Piepiora et al., 2022b) may not be without significance in this matter. It is commonly assumed that bilateral asymmetries have negative effect on sports results, however studies do not confirm such relationship fully (Betsch et al., 2012; Allam and Schwabe, 2013). The area of the pelvic girdle is of special interest due to its complex role in the functioning of humans. Surely, one of the important issues is the effect of correctly aligned pelvic girdle in the spine position (Holmes et al., 2019). Each incorrect position of the pelvis requires back compensation and is a challenge to the control the whole balance process (Pitkin and Pheasant, 1936; Juhl et al., 2004). Pelvic asymmetry is connected with directional biomechanical load (Kurki, 2017). One of the first publications on measuring the position of the pelvis was the work by Pitkin and Pheasant (1936) and Gordon and Davis (2019). They were the first to use the inclinometer measurements to examine the pelvis and analyze the relationship between limb length difference and pelvic rotation. Their first classification of pelvic asymmetries was based on the analysis of radiological images made by Lloyd and Eimbrink. Their system has never been published but only used for educational purposes in the Philadelphia College of Osteopathic Medicine in the early 1950s. The research confirming the connections between pelvic asymmetries and therapeutic practice was validated by Heilig (1978) and Vogt et al. (2020). Gnat and Bialy (2015) proposed an interesting assessment of the pelvic asymmetries. Their method enables the assessment of both asymmetry in the frontal plane and its

TABLE 5 Differences in frequency of occurrence of pelvic girdle asymmetry types depending on gender.

Types of pelvic asymmetry		Women		Men		Women + Men	
		N	%	*N*	%	*N*	%
SP	Type I	49	32.7	26	17.3	75	25
	Type II	6	4	7	4.7	13	4.3
OP	Type III	11	7.3	6	4	17	5.7
	Type IV	24	16	54	36	78	26
RP	Type V	58	38.7	47	31.3	105	35
	Type VI	2	1,3	10	7.7	12	4

OP – Oblique Pelvis; SP – Symmetric Pelvis; RP – Rotated Pelvis; n – number of participants

TABLE 6 Assessment of correlations between anthropometric variables and angle of asymmetry of selected pelvic girdle landmarks.

Variables	Sex	IC		ASIS		TM	
		rho	*p*	rho	*p*	rho	*p*
Weight	♀	0.073	0.373	0.048	0.561	0.177	0.030*
	♂	−0.011	0.896	−0.107	0.191	−0.145	0.077
Height	♀	0.143	0.082	0.086	0.293	0.126	0.373
	♂	−0.140	0.088	−0.115	0.161	0.084	0.304

IC, top of iliac crest angle; ASIS, anterior superior iliac spine angle; TM, top of trochanter major angle; rho, Spearman Correlation Coefficient; ♀, Women; ♂, Men; *, statistically significant differences.

rotation. However, it seems rather time-consuming and does not enable—in the authors' opinion—full differentiation between functional and structural asymmetries. This is a limitation to therapeutic decision-making process. The measuring method includes the asymmetry of the hip to a small extend only (Duboc et al., 2015).

The method of assessing the pelvic symmetry was to be used for initial differentiation of functional and structural asymmetries in the pelvic area. In the right conditions, the lines of the tops of the iliac crests, the anterior superior iliac spines and tops of the trochanter major should run parallel to the floor. With the anthropometric leveler Duometer, not only quantitative but also qualitative data could have been obtained (Preece et al., 2008).

Study limitations

The authors are fully aware that all measurements of the location of bone points on the human body can sometimes introduce an illusory sense of accuracy and reliability. This is due to the fact that the examined bone points are not examined directly but through the body tissues. This applies to most anthropometric studies, even those using advanced methods of three-dimensional analysis. Such an assessment is particularly disturbed by palpation. The use of different measuring instruments reduces the risk of making a mistake, but does not completely eliminate it. Any measurement other than X-ray will always have some error related to the construction of the human body.

During the research, the authors tried to maintain restrictive test conditions to maintain the reliability and repeatability of measurements. Previous studies have shown that measurements using the Duometer show high repeatability under the conditions of tests conducted by an experienced examiner (Bibrowicz and Bibrowicz, 2011a; Bibrowicz et al., 2022).

The results presented herein are a part of a wider research program and are naturally limited to the descriptive analysis of asymmetries. Other aspects of the study, connected with pelvic asymmetry influence on the health, balance, posture quality or other detailed correlations will be presented in the next reports.

Conclusion

1. Asymmetries in the pelvis area are common; they were observed in less than three-quarters of the examined population.
2. Oblique pelvis was found in less than a quarter of women and in more than one-third men with the predominant structural asymmetries.
3. Rotated pelvis was observed in more than one-third of women and men with dominating functional asymmetries.
4. There were no linear correlations between the body mass and height, and the angle of asymmetries.

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.

Ethics statement

The studies involving human participants were reviewed and approved by the Bioethics Board of the Higher School of Physiotherapy in Wroclaw, approval No. 1/2010 of 10.04.2010. The patients/participants provided their written informed consent to participate in this study. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

KB contributed to the conception and design of the study and organized the database. KB, TS, KO-C, BG-W, PK, and ZH performed the statistical analysis, wrote the first draft of the manuscript, and wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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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.

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Relationships between selected indices of postural stability and sports performance in elite badminton players: Pilot study

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The main aim of this study was to determine the relationships between postural stability and the place in the ranking of badminton players. The study examined 10 elite players from Polish national badminton team. The scope of the study included basic somatic characteristics, such as body height, body weight, BMI, and training experience. A Microgate GYKO inertial sensor system was used to assess the postural stability of athletes. Using Spearman's rank correlation, cause-and-effect relationships between the place in the sports ranking and the analyzed variables characterizing postural stability were recognized. Depending on the distribution and homogeneity of variance, the significance of differences in variables that characterize postural stability between players of different sports skill levels (two groups) was calculated. The Student's *t*-test or Mann–Whitney's U-test was used for this purpose. In general, the athletes with higher positions on the ranking list presented a higher level of postural stability in both tests, which is also confirmed by the normalized values. However, for all variables of postural stability, no statistically significant correlations with sports ranking were observed. Higher values of Spearman's rank correlation coefficients were found for the test performed in the one-foot standing test compared to the two-foot test. The results obtained indicate that particular attention in badminton training should be paid to the development of the level of postural stability in order to improve sports performance.

KEYWORDS

badminton, postural control, racket sports, visual information, different sports levels

Introduction

One of the most important coordination motor skills is the ability to maintain balance, which plays a key role because of the significant impact on maintaining a vertical body posture, as well as being essential when performing complex arbitrary movements (Woollacott and Shumway-Cook, 1990; Kubica et al., 2022). A high level of balance is needed in many sports, especially wherever open movement structures (dancing, figure skating, sport gymnastics, badminton, and judo) dominate (Coker and Kaminski, 2020; Slater et al., 2020; Gómez-Landero et al., 2021; Lu et al., 2022; Jaworski et al., 2023). It also determines the safe and independent performance of the basic and instrumental activities of daily living. It contributes to reducing the risk of falls, especially in older adults (Roeing et al., 2017; Cuevas-Trisan, 2019).

Static balance is most often defined as the ability to maintain the projection of the body's center of gravity within the support area (Brachman et al., 2017). For the standing position, this means the area of foot contact with the ground including the surface area between them. From the biomechanical standpoint, it is defined as a state in which the net forces acting on the body are balanced and the sum of moments of these forces is zero (Pollock et al., 2000; Chiari and Cappello, 2005). In the standing position, a human is only seemingly in a state of equilibrium. This is because the human body constantly makes small corrective movements passing through the equilibrium point and moving away from it again. Maintaining balance is possible thanks to the processing of information from the following sensory inputs: from the vestibular organ (labyrinth), from visual, tactile, and proprioceptive systems. The information obtained is processed by the central nervous system and then transferred to the effector organs (Singh et al., 2012; Jaffri et al., 2017).

Another issue is the choice of tools and methods for measuring static and dynamic balance. In population studies (Topendsports, 2023),[1] tests from three groups are most commonly used: Standing Balance (Flamingo Balance, Stork Stand Test, Standing Balance Test, One Leg Stand, and Stick Lengthwise Test), Walking Balance (Beam Walk, Balance Beam Test, Walk and Turn Field Sobriety Test), and Dynamic Balance (Balance Board Test, Bass Test, Star Excursion Balance Test, Y Balance Test, and Multiple Single-Leg Hop-Stabilization). Clinical trials, on the other hand, often use the following tests: Berg Balance Scale (BBS), Timed "Up & Go," Single-leg stance test, 10-Meter Walk Test, BDL Balance Scale, Functional Reach test, Tinetti test, Mini Balance Evaluation Systems Test, and Unified Balance Scale (Lindmark et al., 2012; Takacs et al., 2014; Paillard and Noé, 2015; Hatfield et al., 2016; Bergquist et al., 2019; Kalkan et al., 2021). For many years, various types of balance platforms have been used to assess postural stability. They allow for the assessment of balance based on the displacements of the center of pressure (COP) on the support plane during free standing, which corresponds approximately to the projection of the center of gravity (COG) on the support plane (Błaszczyk, 2008; Lindmark et al., 2012). However, the platforms used have certain disadvantages: first of all, a high purchase price, which limits their widespread use, and they are usually large in size and complicated in use (Mancini et al., 2012). More advanced methods include computerized dynamic posturography on the NeuroCom Smart Equitest system® (Oregon, United States) and Biodex BioSway™ (Miner et al., 2020). Unfortunately, they are not widely used due to their large size, high purchase cost and much more complicated operation.

The above disadvantages and limitations forced the researchers to search for alternative tools to measure postural stability. It seems that different types of accelerometers can be an ideal solution. They are relatively inexpensive, small in size and do not require complicated software (Lindmark et al., 2012; Lesinski et al., 2016). The use of accelerometry (Bourke et al., 2010; Whitney et al., 2011; Marchetti et al., 2013) for recording body sway gained in popularity when the costs of accelerometers with improved measurement parameters declined and wireless technology became widespread. For these reasons, Microgate GYKO triaxial accelerometer was used in our research.

The importance of balance as an essential training element for badminton players, in preventing injuries and improving sports performance, has been highlighted by many authors. Moving around the court requires players to get to the shuttlecock as quickly as possible, while maintaining good balance and keeping the body under control. Malwanage et al. (2022) note the improvement of balance in young badminton players in 8 weeks of training. In the experiment, the control group performed 2 h of standard badminton training, while the experimental group additionally underwent 30 min of balance training, followed by 1 h and 30 min of regular training. Comparing the results before and after the experiment, it was found that both groups improved static balance (eyes open), but only the experimental group improved dynamic balance. On the other hand, a study by Erol (2022) observed the effectiveness of a basic badminton training program in children aged 11–12 on improving balance. The effect of plyometric training on dynamic balance and proprioception of the knee joint of female badminton players was sought in the work of Alikhani et al. (2019). The results of the study showed that a 6-week plyometric training program improved dynamic balance and knee proprioception in novice female badminton players. Investigating the effect of combined balance and plyometric training on the level of dynamic balance and performance of elite badminton players was sought in the work of Lu et al. (2022). Study participants were randomly divided into two groups. Both had the same technical training (badminton techniques for 6 days a week). One group performed balance training combined with plyometric training three times a week for 6 weeks (40 min of plyometrics and 20 min of balance training), while the other group performed only plyometric training (3–4 series × 8–12 repetitions for each exercise). The results obtained indicate that combined training is very promising in improving the dynamic balance and speed of elite badminton players. The necessity of including balance exercises in training programs for athletes of various sports is indicated by the review paper by Brachman et al. (2017). It was based on articles from PubMed and SportDiscus databases published between 2000 and 2016, and included articles on balance training, testing, and injury prevention in young, healthy athletes. In most of the articles analyzed, balance training was found to be an effective tool for improving postural control. However, it is not possible to establish a single training model that is suitable for every sport, as their specific nature and requirements must be taken into account.

The aim of this report was to determine possible relationships between selected indicators of postural stability and the sports ranking of elite badminton players. Furthermore, differentiation of postural stability indices was also sought, depending on the sports skill level of badminton players.

On the basis of the current state of knowledge in the addressed research problem, the following research hypotheses were adopted:

1. Cause-and-effect relationships will be observed between the athletes' position in the sports ranking and selected indicators of postural stability.
2. Due to the nature of the game of badminton, higher correlation coefficients will be observed between the players' position in the sports ranking and the postural stability test performed with one foot than in standing with both feet.

1 https://www.topendsports.com

TABLE 1 Statistical characteristics of basic somatic parameters and age of the study participants.

Variable	$\bar{x}$	SD	V[%]
Body height (cm)	180.80	6.07	3.35
Body mass (kg)	74.40	5.12	6.88
BMI (kg/m^2)	22.78	1.65	7.24
GYKO height (cm)	149.10	8.56	5.74
Age (years)	22.27	4.64	20.83

3. Higher levels of postural stability indices will be observed in athletes ranked higher in the sports ranking lists.
4. It is likely that no statistically significant differences in postural stability will be observed between the results of badminton players classified into two groups by sport level.

Materials and methods

Study group

The study group consisted of 10 males, players from the Polish National Badminton Team with an average training experience of 12.80 ± 2.74 years. In the 3 months prior to the study, all the athletes qualified for the study did not report any serious injuries, such as ankle or knee joint injury, chronic ligament dislocation, or other injuries to the lower limb. They also did not report neurological problems related to balance disorders. The research was carried out during the starting period during the players' preparatory camp grouping. All badminton players participating in the training camp who consented to the study were covered. Thus, it was a purposive selection.

The observed population was a group of players competing in top-rank national and international tournaments. Analysis of the level of achievement of these badminton players reveals that all of them had won the highest trophies in national competitions, whereas some of them had participated in the Olympic Games and world championships; therefore, the competitors were elite Polish badminton players.

The tests and anthropometric measurements were performed in accordance with the Declaration of Helsinki. The examinations were approved by the Bioethics Committee at the Regional Medical Chamber in Kraków, Poland (approval No. 159/KBL/OIL/2017).

Testing protocol

The participants performed all the tests barefoot, in the same room, between 11 a.m. and 2 p.m. Postural stability tests were conducted in a separate room providing peace and quiet for the badminton player being tested. The tests were conducted at a temperature of about 22°C providing thermal comfort. All postural stability tests were performed by the first author of the report. Before the test, the players did not perform warm-ups or other physical activity. During the examination, the athletes had their feet placed straight, with no rotation in the talocrural joint. Feet were spread to the width of the hips, whereas upper limbs were freely positioned along the torso. Immediately after the completion of this test, the contestants performed a one-legged test. They chose the dominant lower limb, whereas the other limb was bent in the knee joint at an angle of about 90°, with the upper limbs freely positioned along the torso. The Waterloo Footedness Questionnaire-Revised (WFQ-R) was used to determine the dominant limb (van Melick et al., 2017). During both tests, the athletes looked at the black point marked on the wall, 2 m away. The duration of each test was 30 s. During the first examination, we determined the height at which the GYKO system was to be attached. According to the manufacturer's recommendations, this height should be set at the level of the T1 thoracic vertebrae (determined by palpation based on spinous processes). The tension of the GYKO attaching straps (chest circumference) was also adjusted to each player. The wireless transmission protocol was used to transfer data recorded by the GYKO inertial sensor to the laptop (Lenovo Yoga 500-15 i5-6200/8GB/1000/Win10).

Scope of the study

Somatic characteristics were measured using the Martina technique. These included the following variables: body height (b-v), GYKO high (b-T1), and body mass (TANITA TBF-551 body composition analyzer). Measurements of somatic characteristics were taken by an experienced person employed by the "Motoric Laboratory." Table 1 presents the basic statistical characteristics of age and selected somatic characteristics of the badminton players studied.

The focus of the analysis was on the following variables that characterize postural stability (Gyko, 2022)[2]:

1. Area (mm^2): The 95% ellipse of confidence is the ellipse that contains approximately 95% of the points of the trajectory.
2. Area Convex Hull (mm^2): The Convex Hull is the smallest polygon that contains all the points of the trajectory.
3. Length: It is the total length of the trajectory obtained as the sum of the distances from one point to the next.
4. Length ML (medio-lateral; mm): The ML length is the total distance in the medio-lateral direction given as the sum of the absolute distances between two consecutive points in the ML direction.
5. Length AP (antero-posterior; mm): The AP length is the total distance in the anteroposterior direction given as the sum of the absolute distances between two consecutive points in the AP direction.
6. Mean Distance: This is the mean distance from the midpoint of the trajectory.
7. Mean Distance ML (mm): This is the mean distance from the midpoint of the medio-lateral trajectory.
8. Mean Distance AP (mm): This is the mean distance from the midpoint of the antero-posterior trajectory.
9. RMS Mean Distance: This is the dispersion of the distance (root mean square). In this case, as the points are centered on the mean, it is equivalent to the Standard Deviation.

2 www.gyko.it

10. RMS Distance ML (mm), AP (mm): This is the dispersion of the distance (root mean square). In this case, as the points are centered on the mean, it is equivalent to the Standard Deviation.
11. Mean Velocity: This is the mean travel velocity of the trajectory.
12. Mean Velocity ML (mm/s): This is the mean travel velocity of the trajectory in medio-lateral direction.
13. Mean Velocity AP (mm/s): This is the mean travel velocity of the trajectory in antero-posterior direction.

The sports skill level of the tested players was determined based on classification lists drawn up by the Polish Badminton Association (Polski Związek Badmintona, 2019; www.pzbad.pl).

Statistical analysis

1. The Shapiro–Wilk test was used to test variables for normal distribution, whereas the Levene's test was employed to assess the equality of variances.
2. The Spearman's rank correlation coefficients between the postural stability indices and the place on the players' ranking list were calculated (17).
3. The whole material was divided into two groups according to the sports skill level: high-level group ($n = 5$) and low-level group ($n = 5$). The basis for the division of players into two groups (depending on the sports level) was the current sports ranking (the list of the Polish Badminton Association) and the subjective classification of players proposed by the two coaches of the national team (purposive selection).
4. Depending on the distribution and homogeneity of variance, the significance of differences was calculated between groups with different sports skill levels. The Student's *t*-test or Mann–Whitney's U-test was used for this purpose. Furthermore, the effect size (Cohen, 1998) was also computed and interpreted as follows: ES > 0.2 = small, > 0.5 = medium, > 0.8 = large.
5. The size, range, and direction of differentiation of the tested indices of postural stability between the selected groups of badminton players were determined based on standardized differences. Standardization was performed for the group mean and standard deviation of the first group.

The calculations were performed using the STATISTICA 13.1 PL for Windows software package with the level of significance set at $p \leq 0.05$. Furthermore, the effect size was determined by means of GPower 3.1 freeware, which is widely used in social studies (Faul et al., 2007).

Results

The analysis will be started with Spearman's rank correlation between the selected postural stability parameters and the place on the players' ranking list. As results from Table 2, all correlation coefficients turned out to be statistically insignificant for the 2-ft standing test. It should be emphasized that in the adopted methodology, a positive sign of the correlation coefficient indicates the desired direction of relations between the analyzed variables, i.e., players classified higher on the ranking list had a higher level of postural stability indices. The athletes' ranking showed the highest positive correlations with Convex Hull Area, Length, and Mean Velocity—correlation coefficients were about 0.30. Furthermore, negative correlation coefficients were obtained only for Mean Distance ML (−0.31) and RMS Distance ML (−0.13). This demonstrates that players with a worse position on the ranking list had higher results of both variables. Table 2 also shows correlation coefficients for the standing test performed on one leg. All correlation coefficients between the variables characterizing postural stability and the position on the ranking list were found positive. Therefore, the athletes with higher positions on the ranking list presented again a higher level of postural stability. The highest correlation coefficients (at the limit of statistical significance) were obtained for such variables as Area, Convex Hull Area, Mean Distance, and RMS Distance, and ranged from 0.41 to 0.50. Analysis of the rank correlation coefficients indicates that greater concurrence was observed between the place in the ranking and the results of the one-legged test compared to the 2-ft test.

Basic statistical characteristics of parameters characterizing postural stability for the 2-ft test performed in groups depending on sports skill level are presented in Table 3. The results of the Student's *t*-test revealed no statistically significant differences for all the variables characterizing postural stability. It is known that statistical significance depends on the effect size, but also on the sample size. Therefore, for a large sample, even a very small effect will be important. Taking into account the practical significance of the research, effect size should be documented simultaneously with the evaluation of the significance of differences, which is performed in this study. In our study, the greatest effect size (ES) of 0.71 was obtained for: Length AP (mm), Mean Velocity AP (mm/s), then for: Length (mm), Mean Velocity (mm/s)—0.59. The mean effect size was found for Convex Hull Area (mm^2) and Area (mm^2; ES of *ca.* 0.5). No effect size was found for variables: Mean Distance (mm), Mean Distance AP (mm), Mean Distance ML (mm), RMS Distance (mm), RMS Distance AP (mm), and RMS Distance ML (mm).

Regardless of the statistical analysis of the significance of mean differences, the analysis of standardized intergroup differences of analyzed parameters of postural stability provides interesting information. Such a methodological approach allowed for the analysis of the differentiation within all the tested properties (measured in different units). Analysis of the system of standardized differences revealed that a higher level of all parameters is presented by higher-ranked badminton players. In the case of the 2-ft standing test, the effect of the sports skill level on the results was the most pronounced: Length AP (mm), Mean Velocity AP (mm/s). A relatively large variation, in favor of the group with higher sports skill level, was also obtained for: Area (mm^2), Length (mm), Mean Velocity (mm/s). The standardized values for these variables were *ca.* −0.70 SD.

Basic statistical characteristics of parameters characterizing postural stability for the one-foot test performed by both groups depending on sports skill level are presented in Table 4. The results of the Student's *t*-test and Mann–Whitney's U-test revealed no statistically significant differences for all the variables characterizing postural stability. However, a characteristic system of arithmetic means can be observed for all analyzed variables, with better results in the group with a higher sports skill level. According to the classification proposed by Cohen, the effect size for 12 variables should be considered medium (values of statistics ranged from 0.50 to 0.80). Table 4 also presents the standardized intergroup differences of

TABLE 2 Spearman's rank coefficients between selected postural stability parameters and the place of the player in the ranking.

Variable (Unit of measurement)	Two-feet test Spearman's rho	Two-feet test 95% confidence interval (CI)	One-foot test Spearman's rho	One-foot test 95% confidence interval (CI)
Area (mm^2)	0.24	−0.46 ± 0.76	0.50	−0.19 ± 0.86
Convex hull area (mm^2)	0.30	−0.41 ± 0.78	0.44	−0.26 ± 0.84
Length (mm)	0.31	−0.40 ± 0.79	0.38	−0.33 ± 0.81
Length AP (mm)	0.22	−0.48 ± 0.75	0.35	−0.36 ± 0.80
Length ML (mm)	0.26	−0.44 ± 0.76	0.41	−0.30 ± 0.83
Mean distance (mm)	0.18	−0.44 ± 0.76	0.43	−0.27 ± 0.83
Mean distance AP (mm)	−0.02	−0.62 ± 0.64	0.20	−0.49 ± 0.74
Mean distance ML (mm)	−0.31	−0.79 ± 0.40	0.15	−0.53 ± 0.71
RMS distance (mm)	0.12	−0.55 ± 0.70	0.43	−0.27 ± 0.83
RMS distance AP (mm)	−0.02	−0.64 ± 0.62	0.31	−0.40 ± 0.79
RMS distance ML (mm)	−0.13	−0.70 ± 0.54	0.25	−0.45 ± 0.76
Mean velocity (mm/s)	0.31	−0.40 ± 0.79	0.38	−0.33 ± 0.81
Mean velocity AP (mm/s)	0.22	−0.48 ± 0.75	0.35	−0.36 ± 0.81
Mean velocity ML (mm/s)	0.26	−0.44 ± 0.76	0.41	−0.30 ± 0.83

*Statistically significant correlation coefficients at $p \leq 0.05$.

TABLE 3 Basic statistical characteristics of postural stability parameters, evaluation of the significance of intergroup differences and effect size (2-ft test).

Variable [unit of measurement]	Two-feet test high-level group		Two-feet test low-level group		*t*	*p*	z	ES
	arithmetic mean	SD	arithmetic mean	SD				
Area (mm^2)	398.19	141.34	497.36	242.31	−0.79	0.45	−0.70	0.50
Convex hull area (mm^2)	276.82	118.52	354.32	161.80	−0.86	0.41	−0.65	0.54
Length (mm)	217.09	43.12	247.85	59.77	−0.93	0.38	−0.71	0.59
Length AP (mm)	157.81	22.59	186.85	53.15	−1.12	0.29	−1.29	0.71
Length ML (mm)	115.84	37.53	125.87	26.78	−0.49	0.64	−0.27	0.30
Mean distance (mm)	7.74	1.32	7.61	2.70	0.10	0.92	0.10	0.06
Mean distance AP (mm)	6.73	1.81	6.51	2.66	0.15	0.89	0.12	0.09
Mean distance ML (mm)	2.93	0.83	2.87	0.74	0.11	0.91	0.07	0.07
RMS distance (mm)	8.75	1.30	8.76	3.21	−0.01	0.99	−0.01	0.00
RMS distance AP (mm)	7.94	1.69	8.00	3.23	−0.04	0.97	−0.04	0.02
RMS distance ML (mm)	3.45	0.91	3.45	0.91	−0.01	0,99	0.00	0.00
Mean velocity (mm/s)	10.85	2.16	12.39	2.99	−0.93	0.38	−0.71	0.59
Mean velocity AP (mm/s)	7.89	1.13	9.34	2.66	−1.12	0.29	−1.28	0.71
Mean velocity ML (mm/s)	5.79	1.88	6.29	1.34	−0.49	0.64	−0.27	0.30

*Statistically significant differences at $p \leq 0.05$.

t, Student's *t*-test value, U, Mann–Whitney U-test value (with continuity correction), *z*, standardized values, ES, effect size, > 0.2 = small, >0.5 = medium, >0.8 = large.

the analyzed variables characterizing postural stability. Standardized group differences range from −0.11 SD to −1.00 SD. Analysis of the system of standardized differences revealed unequivocally that a higher level of all parameters is presented by higher-ranked badminton players (those with a higher position in the ranking). The largest normalized differences were obtained for variables: Length ML (mm) and Mean Velocity ML (mm/s).

Discussion

In sports training, the aim should be to recognize mutual cause-and-effect relationships between its type, somatic, energetic, coordination, and mental aptitudes and the development of the results achieved. The effectiveness of badminton playing depends on many combinations of factors which affect the player during the whole

TABLE 4 Basic statistical characteristics of postural stability parameters, evaluation of the significance of intergroup differences and effect size (one-foot test).

Variable (Unit of measurement)	One-foot test high-level group		One-foot test low-level group		*t*	*p*	z	ES
	arithmetic mean	SD	arithmetic mean	SD				
Area (mm^2)	3128.04	2543.64	4817.60	2688.49	−1,02	0.34	−0.66	0.64
Convex hull area (mm^2)	2211.98	1831.18	3349.38	1823.37	7.00^U	0.29	−0.62	0.62
Length (mm)	620.63	203.18	809.30	355.69	−1.03	0.33	−0.93	0.65
Length AP (mm)	406.79	104.65	485.62	160.59	−0.92	0.38	−0.75	0.58
Length ML (mm)	381.28	159.80	541.29	303.11	9.00^U	0.53	−1.00	0.66
Mean distance (mm)	17.82	7.87	21.83	7.65	−0.82	0.44	−0.51	0.51
Mean distance AP (mm)	11.24	5.93	14.84	8.15	−0.80	0.45	−0.61	0.50
Mean distance ML (mm)	11.45	5.82	12.10	5.13	−0.76	0.47	−0.11	0.11
RMS distance (mm)	19.72	8.57	24.14	8.38	−0.82	0.43	−0.52	0.52
RMS distance AP (mm)	13.50	6.83	18.02	9.54	−0.86	0.41	−0.66	0.54
RMS distance ML (mm)	13.67	7.19	14.64	5.85	−0.23	0.82	−0.13	0.14
Mean velocity (mm/s)	31.03	10.16	40.47	17.78	−1.02	0.33	−0.93	0.65
Mean velocity AP (mm/s)	20.34	5.23	24.28	8.03	−0.92	0.38	−0.75	0.58
Mean velocity ML (mm/s)	19.06	7.99	27.06	15.16	9.00^U	0.53	−1.00	0.66

Symbols the same as in Table 3.

training process (Lees, 2003; Chansrisukot et al., 2015; Phomsoupha and Laffaye, 2015; Tomaszewski et al., 2018). An adequate level of coordination motor abilities is especially important in badminton. It is forced by the complex nature of the game, which requires the use of movement activities of high complexity and adaptation to constantly changing situations on the court (Wang et al., 2008, 2009; Poliszczuk and Mosakowska, 2009; Bańkosz et al., 2013; Jaworski and Żak, 2015; Kosack et al., 2020; Cui et al., 2022).

The high level of balance allows badminton players to use all their muscle strength and speed in a variety of categories of techniques such as smash, clear, and drop shot (Phomsoupha and Laffaye, 2015). During the game, players constantly follow the moving shuttlecock and quickly change their body position. The athletes attempt to maintain the projection of the body's center of gravity (COG) within the support area by making very fast and asymmetrical movements of the upper limbs. On the other hand, after the action is completed, they have to quickly return to the correct starting position and prepare for the next play (Wong et al., 2019). A good balance also determines a more balanced landing on the ground after a jump, helps move faster on the court, and is an important factor in avoiding badminton injuries (Yung et al., 2007; Herbaut et al., 2018). The importance of balance for the playing performance in various positions (front court play, back court strokes, and jump smash). Therefore, improved body balance is critical for the development of movement skills in badminton and therefore determines high playing performance (Masu et al., 2014; Hamed and Hassan, 2017). The aim of the research was to fill the gap concerning the effect of balance on the playing performance of badminton players. Such reports have been very rare so far and therefore the authors point to the necessity of exploration of this area (Masu et al., 2014; Wong et al., 2019). The analysis of our results reveals positive correlations between selected parameters of postural stability and the position on the ranking list of badminton players. Much higher coefficients of correlation with the ranking for the one-foot test performed on the dominant limb were observed compared to the 2-ft standing test. As found by Wong et al. (2019) multi-plane movements, rapid changes in the player's position, numerous jumps and lunges with the dominant lower limb, and the way the player moves around the court are specific to the game of badminton. Thus, it can be concluded that the results of the present study confirm this relationship. Badminton forces players to perform frequent jumps, sudden directional changes on the court, broad range of movements of the upper limbs, and frequent changes in body positions (Tiwari et al., 2011; Hu et al., 2015). For these reasons, the results of our research are obvious and likely to result from the nature of the dominant play in various unstable positions during competitions.

The analysis of the effective playing time revealed that the energy is largely fueled by aerobic pathways (around 60–70%), while around 30% of the energy is generated from anaerobic processes (Phomsoupha and Laffaye, 2015). The effect of fatigue on the results of dynamic balance in the Y balance test (YBT) was indicated by Sarshin et al. (2011). These authors found a decrease in the dynamic balance of the body after functional fatigue. For this reason, badminton players may be exposed to various injuries in the lower limbs. Similar findings were reported by Alikhani et al. (2019). Badminton players should be characterized by a high level of dynamic balance to prevent musculoskeletal injuries, especially non-contact anterior cruciate ligament (ACL) injuries. Therefore, badminton coaches and players can use plyometric training to improve dynamic balance, which in turn can reduce non-contact ACL injuries. Furthermore, Lu et al. (2022) also showed that balance training combined with plyometric training can enhance dynamic balance ability and improve the performance of male elite badminton players. The need for greater emphasis on stability training in junior badminton players was demonstrated by Vora et al. (2018). Understanding its importance in

the overall improvement of sports performance is a must and can produce good results in the next stages of sports training.

Modern technological developments increasingly allow the use of various types of accelerometers (usually triaxial) to measure postural stability. Particularly after the cost of such tools was reduced and wireless technology was used, they became popular in scientific research. The ICCs reliability results of postural stability measurements obtained with accelerometers are good and are usually above 0.75 (Marchetti et al., 2013; Saunders et al., 2015; Guo et al., 2022). The GYKO accelerometer (Microgate Italy) used in our study has high reliability and accuracy of measurement. It has been used in a number of studies that have looked at various aspects of human motor skills (Lesinski et al., 2016; Arede et al., 2019; Santospagnuolo et al., 2019; Hamersma et al., 2020). In a study by Jaworski et al. (2020), the authors determined the reliability of a GYKO accelerometer. The results that characterize postural stability indices showed high and satisfactory values of intraclass correlation coefficients (ICCs) between test and retest data (ICCs values ranging from 0.62 to 0.70).

So far, most research has been devoted to the comparison of the level of selected coordination skills between athletes practicing different sports and non-athlete peers and athletes at different sports skill levels. In this area of research, the greatest achievements concern comparisons of reaction time. The review of the results indicates that badminton players had shorter reaction times compared to those from non-athlete control groups (Bańkosz et al., 2013; Dube et al., 2015). Furthermore, Yüksel and Tunç (2018) demonstrated that the reaction times of young badminton players from the highest-ranked countries were better. Wong et al. (2019) compared the level of dynamic and static balance in badminton and control group players, without any significant differences between the groups. These results are slightly different from other studies indicating that badminton training can improve balance. The authors explain this by the age of the players surveyed, who had already developed an almost mature postural control system, so the potential for further improvement could be limited. Furthermore, the control group consisted of physically active individuals, which probably had a positive effect on the level of their balance abilities.

In our study, we also compared selected variables characterizing postural stability between badminton players with different sports skill level. For both analyzed samples, the differences in mean results were statistically insignificant. However, analysis of the system of standardized differences revealed that a higher level of all parameters was presented by players from the group with a higher sports skill level. The calculated Cohen effect size should be regarded as medium for most variables. These regularities are particularly noticeable for the test performed on the dominant limb. Research on the displacements of the center of gravity (COG) of eight high-level athletes (belonging to the top three teams of the Badminton Championship in Japan) and eight amateur badminton players playing in university clubs was carried out by Masu et al. (2014). In the test with eyes open, the COG was maintained in the high-level group close to the center, while the low-level group moved it more toward the dominant leg. In the test with eyes closed, the length of the statokinesiogram path, the sway area, and the amplitude of sway in the X and Y axes were larger in the group with lower sports skill level. The quoted results are consistent with our findings. Furthermore, Yüksel et al. (2015) demonstrated that the 8-week training of young badminton players improves dynamic balance. Similar conclusions were presented by Masu et al. (2014), who stated that training can improve static balance in standing on one limb with eyes closed. Therefore, the observed results may have been caused by long-term physical training, which leads to specific and plastic changes in the central nervous system (Masu et al., 2014).

We believe that in the training programs of badminton players, special attention should be paid to the formation of balance. The training structure should include various types of static and dynamic balance exercises. Balance exercises should take into account different positions (one-legged, two-legged, and tandem), the ground (stable, unstable), and be conducted with eyes open and with the removal of visual feedback.

Limitation of the study

It is necessary to study the effects of basic postural stability training in badminton players of different training seniority as well as sports level. Such studies should be conducted in different age groups in both sexes.

Further studies are needed in groups with much larger numbers of individuals.

Postural stability studies should be conducted with consideration of different starting positions, with eyes open or closed and on a stable or unstable surface.

The use of alternative measurement tools for assessing balance should also be considered (stabilometric platforms, stabilographic single-plate or dual-plate versions, and balance boards).

Conclusion

The results presented in the study lead to the following conclusions:

1. Spearman's rank correlation coefficients indicate the cause-and-effect relationships between the ranking of badminton players and postural stability indices. These relationships are particularly noticeable for the one-foot test performed on the dominant limb.
2. A higher level of postural stability is observed by badminton players classified higher on the ranking lists.
3. The results obtained indicate that particular attention in badminton training should be paid to the development of the level of postural stability in order to improve sports performance.
4. Further research should be conducted for different training groups and sports skill levels in order to confirm the effect of balance training on the effectiveness of playing badminton.

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.

Ethics statement

The studies involving human participants were reviewed and approved by Bioethics Committee at the Regional Medical Chamber in Kraków, Poland (Approval No. 159/KBL/OIL/2017). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JJ, GL, and MŻ contributed to conception and design of the study. JJ and MŻ organized the database. JJ and GL performed the statistical analysis. JJ, KW, and PP wrote the first draft of the manuscript and wrote the sections of the manuscript. All authors contributed to the article and approved the submitted version.

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.

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A pilot study of a modification EAT-26 questionnaire for screening pathological eating behavior in competitive athletes

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This study deals with pathological forms of eating behavior and disorders of athletes with the aim to verify a newly created questionnaire method focused on their screening. First, a detailed analysis of one of the most frequently used methods, EAT-26, was carried out, which was subsequently reworked into a newly created questionnaire that should meet the criteria for application to a group of competitive athletes. This new questionnaire was then verified on a group of athletes in risky sports disciplines. It was distributed among athletes of aesthetic sports, specifically among aerobics (gymnastic, sport, and fitness), gymnastics (modern and sport), professional dance, figure skating, and bodybuilding/fitness (classic bodybuilding, bikini fitness, and men's physique). In total, 100 respondents, 79 women and 21 men, with 20 persons from each sport branch, aged 16–26, participated in the research. The main results of the research investigation were determined using factor analysis, which yielded positive results. Five strong factors (dietary control, body weight control, training obsession, appetite, and calorie counting) were identified, which can be defined as common and well-known characteristics in the eating and training regime of competitive athletes. At the same time, the factors found can be defined as essential factors influencing the emergence of disturbed eating behavior or the later development of an eating disorder. Compared to the original EAT-26, the point score was adjusted, and its critical value was determined at 57 points. Of the respondents, 33%, i.e., 33 out of a possible 100, achieved this value or above. Respondents with a point score of 57 and above were found in every sport tested. Of the 33 respondents reaching this point limit, 6% were in aerobics, 24% in gymnastics, 15% in professional dance, 27% in figure skating, and 27% in bodybuilding/fitness. Respondents from the bodybuilding and fitness sports sector achieved the highest number of points on average and those were the only ones who exceeded the threshold of 57 points on average. The results of the work correspond with the opinion of many experts that the sports environment is ideal for covering up disturbed eating behavior or eating disorders, and diagnosis in this environment is difficult.

KEYWORDS

EAT-26, Eating Attitudes Test, pathological eating behavior, eating disorders in athletes, anorexia athletica

1. Introduction

We see the topic of pathological eating behavior and psychogenic eating disorders in athletes as extremely relevant. Their incidence is probably much higher than assumed because, among other issues, we lack effective diagnostic tools.

Psychogenic eating disorders in athletes and their causes and manifestations are not identical to their causes and manifestations in the general population. They are far more connected to athletic performance and success in sports than body appearance and body weight (Byrne and McLean, 2001). Contemporary sport at the top-level places extreme demands on athletes in all aspects, including nutrition, and this is all the more relevant in aesthetic sports or in sports in which body weight plays a role within the division into weight categories or as an advantage when performing the sport itself. In some sports, there are fundamental changes in body weight during competitive and non-competitive periods.

For pathological eating behavior in athletes, the term sports anorexia (anorexia athletica) is commonly used. This is a condition described in athletes who restrict energy intake, engage in excessive to extreme exercise, or engage in both, in order to achieve or maintain a low body weight as a way to maximize their athletic performance (Dunford and Doyle, 2007).

Plowman and Smith (2007) states the following diagnostic criteria for anorexia athletica: body weight loss (at least 5% below normal for given age and height), absence of any other health problems that would explain the body weight loss, excessive fear of being overweight, energy intake below 1,200 kcal per day, delayed puberty, amenorrhea or oligomenorrhoea, consumption of foods with low energy content, gastrointestinal problems, disturbed perception of one's own body, excessive to extreme exercise, and compulsive need for exercise beyond the training regime.

Personal risk factors for the emergence of pathological eating behavior in athletes may include those that are described as typical for athletes, namely competitiveness, determination (motivation), and perfectionism, which is most often mentioned in various works (Dosil, 2008; Bean, 2013).

Bean (2013) describes the factors influencing the development of eating disorders in athletes as the demands of the given sport, pressure from the coach or teammates, social and media pressure, and pressure from the family environment. Dosil (2008) lists a wider spectrum, namely weight restrictions in sports, referee criteria, physical demands of sports that require an extremely low percentage of body fat, pressure from the coach, and pressure from teammates. A similar list is given by Berning and Steen (2005): early specialization in training, diets and cycles, traumatic events, the influence of coaches, and the rules of the given sport discipline.

There are a number of methods for diagnosing disordered eating behavior and eating disorders. The format of a structured interview is usually seen as the most effective method. A structured diary format also offers objective assessment. Many scientists and researchers use less time-consuming questionnaires for their studies (Fichter and Quadflieg, 2000).

The Eating Attitude Test by Garner and Garfinkel is probably the most widely used standardized measuring gauge of symptoms characteristic of eating disorders. The original version of the test is the EAT-40 version, which was first published in 1979 and was used in one of the first studies, which focused on examining sociocultural factors in the development and maintenance of eating disorders. Based on this version of the test, a new and more advanced version was created, which was called the EAT-26. Since then, the test has been translated into many languages and used in hundreds of studies. The original publication of the test (1979) and the subsequent publication describing the refinement of the test (1982) are ranked 3rd and 4th, respectively, on the list of the 10 most cited articles in the history of the magazine of Psychological Medicine. Founded more than 40 years ago, this journal has allowed the Eating Attitudes Test to make a huge impact in the field of eating disorders (Garner, 2017). The Eating Attitudes Test published in 1979 by Garner and Garfinkel is also found by Nathan and Allison (1998) to be the most widely used method for assessing eating disorders. But it is very significant that it cannot distinguish between anorexia nervosa and bulimia nervosa.

Screening for eating disorders is based on the premise that early recognition of the disorders can lead to earlier treatment and thereby reduce serious physical and psychological complications or, in the worst cases, even death. The test should be part of the so-called two-step screening process and should be the first step. The second step is usually determined according to the given methodology related to the final test score. According to this methodology, a respondent with a point score above 20 points should be invited to an interview with a qualified expert (EAT-26, 2017).

The Eating Attitudes Test is based on the following three criteria (EAT-26, 2017):

- *The total score based on answers to EAT test questions.* A score of 20 points or higher indicates an increased risk of one of the eating disorders. It points to an individual's increased interest in eating and body weight, or disturbed eating behavior itself.
- *Answers to questions concerning the behavior associated with eating and weight loss.* If the respondent answered yes to any of the questions regarding disordered behavior, they should seek a qualified mental health professional who specializes in dealing with eating disorders.
- *Body mass index (BMI) calculated according to height and body weight.* The Eating Attitudes Test contains specific questions about body height, body weight, and gender, the answers to which can be used to calculate body mass index (BMI).

The test is available in a long 40-item version and in a shortened 26-item version, both versions rated on a six-point Likert scale (1 = never, 6 = always). The questions are closed, and the respondent can choose from six answers: always, very often, often, sometimes, rarely, and never. In the evaluation, each answer is assigned a certain number of points. For questions 1–25, they are evaluated as follows: always = 3 points, very often = 2 points, often = 1 point, sometimes, rarely, and never = 0 points. Question 26 is evaluated in the opposite way: always, very often, often = 0 points, sometimes = 1 point, rarely = 2 points, never = 3 points. The resulting sum of points describes the individual's eating behavior, with a score of 20 and above defined as disordered eating behavior. Dosil (2008) states that the Eating Attitudes Test focuses on three main factors, namely dieting behavior, bulimia and increased interest in food and oral control. It consists of questions about avoiding high-calorie foods, thoughts or anxiety about food and its ingredients, self-control in the area of food intake, and questions about the perception of pressure from others regarding body weight and weight gain/loss.

At this point, we also present a clear table of diagnostic questionnaire methods focused on pathological eating behavior and eating disorders, the comparison of which was used when selecting the method for our study (Table 1).

2. Objective

The main objective of our study was the creation of a method that will be applicable to competitive athletes, who are a highly specific group, without completely creating a new method, but instead modifying the most used questionnaire method EAT-26. The created screening method should be able to recognize pathological forms of eating behavior or eating disorders in athletes. The main difference from the previously developed screening and diagnostic methods intended for athletes and non- should be the inclusion of all important aspects of the athlete's life in the questionnaire (with regards to the type of sport, type of competition, training regimen, and diet regimen).

The opinion that the current form of the EAT-26 is not ideal for screening eating disorders in athletes is shared by Martínez Rodríguez et al. (2015), who in his study focused on pathological eating behavior in contact sport athletes. On the contrary, Garfinkel and Newman (2001) in their article reflecting on the EAT-26 test's 25 years of existence, report without doubt on the suitability of this test for athletes and emphasize that the most vulnerable group, as far as eating disorders are concerned, are top-level and professional athletes.

3. Characteristics of the research group

The research was conducted on a group of competitive athletes. In order to include a respondent in the research group, the presence of three basic factors was necessary:

- Partakes in a specific training program.
- Partakes in a specific eating program (none of the athletes were currently following a restrictive diet aimed to athletes primarily reduce body weight due to competition weight categories, these were athletes in disciplines where a long-term dietary modification focused on body composition is necessary).
- An active status of an athlete—participation in amateur level competitions/races.

The questionnaire was distributed among athletes of aesthetic sports, namely aerobics (gymnastics, sports, and fitness), gymnastics (modern and sports), professional dance, figure skating, and bodybuilding/fitness (classic bodybuilding, bikini fitness, and men's physique).

In total, 150 respondents participated in the research survey. The return rate of the questionnaire was 88%, or 132 returned samples. Based on incorrect or incomplete filling in, some samples had to be discarded; out of the total 132 returned samples, 106 samples remained for use. Due to large age differences and some sports sectors being more predominant, further samples were subsequently discarded. Therefore, the total number of questionnaires used equals 100 samples. Of the 100 available samples, 79 women and 21 men (mostly bodybuilders—13 bodybuilding, four gymnastics, and four dance) participated in the research investigation. Furthermore, out of the 100 available samples, 20 samples were from each sports sector. The age limit of the respondents ranged from 16 to 26 years. The arithmetic mean was 20.7 years, modus and median 20 years, standard deviation 2.33 (Figure 1).

4. Methods

In general, the EAT test focuses on three main factors: dieting behavior, bulimia, and increased interest in food and oral control. The utilized version of the test contains 26 closed questions with a choice of 6 scale answers (always, very often, often, sometimes, rarely, and never).

There was an analysis of individual test questions and their possible modification according to the difference between the general population and athletes (functional sports nutrition is characterized primarily by the control of energy intake, nutrients intake, their timing in relation to training and, with it, great demands on self-control, as well as control of body weight and body composition).

Question No. 1 *I am afraid of being overweight* was rephrased as *I am afraid of gaining body weight despite my strict diet and training regime.*

Question No. 2 *I avoid eating when I'm hungry* was eliminated.

Question No. 3 *I think of myself as worrying too much about food* was changed to *I feel anxious if I am not in control of my diet regimen.*

Question No. 4 *It happens that I start to overeat, and I feel like I will not be able to stop* was changed and questions were created to determine the athlete's relationship to overeating *In my strict regime, I treat myself to one "cheat day," When I have a "cheat day" or I am on an "off season mode," I eat, even when I am no longer hungry or do not have appetite. After a "cheat day" or after eating something that is not on my diet plan, I feel sick and have a guilty conscience.*

Question No. 5 *I cut food into small pieces* was eliminated.

Question No. 6 *I am aware of the caloric value of the food I eat* was kept and enriched with other questions determining the degree of seriousness of awareness of the caloric value of meals: *I am aware of the caloric value of the food I eat, I count my calorie intake, I feel anxious if I do not have an overview of the caloric values of the food I eat, I do not eat any food whose caloric value I do not know and does not fit my caloric intake, When I eat my daily caloric intake, I'm usually resigned to not eating anything again.*

Question No. 7 *I often avoid foods high in carbohydrates (bread, potatoes, rice,* etc.*)* was edited and more questions were added: *Avoiding foods with a high carbohydrate content (bread, potatoes, rice,* etc.*) is part of my diet plan, When I eat a meal with a high content of carbohydrates, I am afraid of gaining body weight.*

Question No. 8 *I feel that others would like me to eat more* was eliminated.

Question No. 9 *I vomit after eating* was eliminated.

Question No. 10 *I feel very guilty after eating* was excluded from the questionnaire due to its inapplicability to the group of athletes.

Question No. 11 *I think too often about wanting to be slimmer* has been changed and additional questions were added to determine the athlete's relationship to their energy intake: *I feel that my diet regime and training are insufficient and I would like to be slimmer, Despite my special diet and training regimen, I deliberately reduce energy intake to be slimmer, I want to*

TABLE 1 Overview table of diagnostic questionnaire methods.

Method name	Year of publishing	Author	Specialization	Length	Advantages	Disadvantages
EDE	1987	Cooper and Fairburn	The psychopathology of eating disorders	–	Interviewee and interviewer interaction	Time-consuming, necessity of trained professional staff
EDDS	2000	Stice et al.	Symptoms of anorexia nervosa, bulimia nervosa and binge eating disorder	22 items	Strong validity and reliability, easy applicability and evaluation	It does not reflect the fact that behavioral symptoms are much less consistent than cognitive symptoms
QEED	1997	Mintz et al.	Assessment of presence of anorexia nervosa, bulimia nervosa and 4 types of EDNOS	50 items	Fast filling, easy evaluation, high sensitivity	Choice of answers only yes/no
SIAB	1990	Fichter et al.	Assessment of presence of anorexia nervosa, bulimia nervosa	87 items	Can be used to derive diagnoses	Time-consuming, does not reflect changes in DSM-5 criteria, necessity of professional training of the staff
BULIT-R	1991	Smith and Thelen	Symptoms of bulimia nervosa	36 items	Easy to apply, takes 10 min to complete, good validity and reliability	Evaluation (possibility of false negative results)
EAT	1979	Garner and Garfinkel	Symptoms characteristic of eating disorders	26 items/40 items	Multifunctionality (evaluates a range of attitudes toward food and of eating behavior, identification of individuals at risk, evaluation of treatment), can really distinguish between disordered eating behavior	Cannot distinguish between anorexia nervosa and bulimia nervosa, not applicable for children under 15 (see children's version)
EDE-Q	1994	Faiburn and Beglin	Duration and frequency of eating disorder symptoms	36 items	Good validity and reliability	It is not possible to clarify and make rating judgments about more complex and subjective concepts, it is not possible to assess the complex behavior of an individual
EDI	1983	Garner et al.	Psychometric peculiarities and symptoms related to the development and progress of eating disorders	64 items	Translation into many foreign languages, widely used in the sports environment	Cannot be used separately, the contents of some sub-groups does not relate to eating and body weight, but are general psychopathological scales, does not differentiate between eating disorders and psychiatric patients, use in men
SCOFF	1999	Morgan et al.	Basic characteristics of anorexia nervosa and bulimia nervosa	5 items	High sensitivity, memoizable, good validity and reliability	Very short, does not serve as a diagnostic method - expert evaluation is required

be slimmer and thus improve my athletic performance, I want to be slimmer and thus improve my physical appearance, I do not care about sports performance.

Question No. 12 *When I exercise, I think about how many calories I burn* was changed and additional questions were added to determine the relationship between the individual's feelings and exercise: *If I eat something outside of my meal plan, I usually add an extra workout, I regularly add extra training or exercises, After mastering the training, I feel stronger and more self-confident, If I have to miss my workout, I feel anxious, If I had to choose between hanging out with friends/family and training, I would choose training, Only through training will I get rid of a bad mood and forget about my problems, I exercise when I am sick or injured.*

Question No. 13 *People think I'm too thin* was changed and additional questions regarding the relationship between the coach's opinion and the athlete's behavior were added: *My coach thinks I should be slimmer, My coach's opinion affects my eating behavior.*

Question No. 14 *I keep thinking that I have a lot of body fat* was changed and additional questions were added to determine the basic relationship of an individual to their body, regardless of sports performance: *I feel good in my body, I feel good about my physical "self," I like my body, I nurture and take care of it.*

Question No. 15 *It takes longer for me to finish my food than for others* was excluded.

Question No. 16 *I avoid foods with sugar content* was reformulated in the same manner as question No. 7 and additional questions were

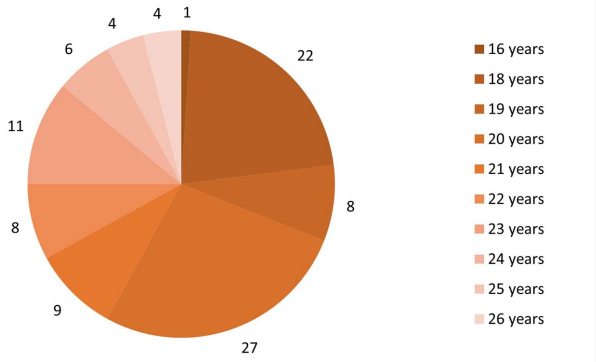

FIGURE 1
Distribution of respondents by age.

added that could potentially capture any pathologies present: *Avoiding foods with sugar content is part of my diet plan, My meal plan allows for foods with sugar content once in a while, I do not eat any food that contains sugar, even though my meal plan allows it, When I eat food that contains sugar, I am afraid of gaining body weight.*

Question No. 17 *I eat diet foods* was excluded from the questionnaire due to its inapplicability to the group of athletes.

Question No. 18 *I feel like food is controlling my life* was excluded.

Question No. 19 *I exercise self-control when it comes to food* was excluded.

Question No. 20 *I feel that others are forcing me to eat* was excluded from the questionnaire due to its inapplicability to the group of athletes.

Question No. 21 *I spend too much time thinking about food* was excluded and replaced by those mentioned above in question No. 3.

Question No. 22 *When I eat sweets, I feel uncomfortable* was amended and additional questions were added regarding the individual's relationship to the consumption of healthy foods: *When I eat something with less healthy ingredients, I feel uncomfortable, I never eat anything if I do not know the exact composition, preparation method, or origin of the food, In principle I prefer to prepare my food by myself, I study in detail the composition and origin of the food on the back of the packaging, When I choose my food, its quality is more important to me than its taste, My diet regimen consists of a rich variety of foods and ingredients.*

Question No. 23 *I follow diets* was excluded from the questionnaire due to its inapplicability to the group of athletes.

Question No. 24 *I like the feeling of an empty stomach* was excluded.

Question No. 25 *After eating, I have the urge to vomit* was excluded.

Question No. 26 *I like to try new substantial foods* was excluded.

From the original 26 questions, a diagnostic tool of 38 questions came into existence. The evaluation for the new tool for detecting pathological forms of eating behavior was adjusted to only a four-point scale: always, often, rarely, and never.

The evaluation was determined in the following manner:

In the questions: 1, 2, 3, 6, 7, 8, 9, 10, 11, 13, 14, 15, 17, 18, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 37

- Always = 3 points
- Often = 2 points
- Rarely = 1 point
- Never = 0 points

In the questions: 4, 5, 12, 16, 19, 22, 34, 38

- Always = 0 points
- Often = 1 point
- Rarely = 2 points
- Never = 3 points

The evaluation of the newly created instrument is based on the same principle as the evaluation of the EAT-26 test. Each answer is assigned a given number of points, after adding them up we get a total score. The cut-off score limit was set at 57 points, i.e., exactly half of the possible points obtained. We followed the evaluation of the EAT-26, where the cut-off score limit was set in the same way. A score of 57 and above may indicate disturbed eating behavior and a potential risk of developing an eating disorder (Table 2).

Exploratory factor analysis method was used for data processing (we did not assume that the factors would remain the same as for EAT-26). Data were processed using SPSS 26 software.

5. Results

Exploratory factor analysis of the newly created questionnaire items led to the following results.

Two questions were excluded during data processing: question No. 14—"*I feel good in my body.*" and question No. 19—"*I feel good about my physical self.*" They showed a completely illogical reversal of the correlation. The cause of this fact may be a poor understanding of the questions by the respondents, or a poor formulation of both questions during the creation of the questionnaire.

Factor analysis among the questionnaire questions found five strong common significant factors, which were:

- Control over diet
- Control over body weight
- An obsession with training
- Appetite for food
- Calculating caloric intake

The factors found are very closely related to the characteristic features of pathological eating behavior in athletes (Figure 2).

Factor F1 included 15 questions, factor F2 included seven questions, factor F3 included five questions, factor F4 included five questions, and factor F5 included three questions (Table 3).

Using the discovered factors, new variables can be created that can be used in further research instead of the original items. When focusing in detail on the original items of the questionnaire, it is possible to observe which questions are grouped under which factor. Important questions related to awareness of the caloric value of food, avoiding individual nutritional components, monitoring the composition of individual foods, etc. are grouped under the Control over the diet factor. Respondents with this factor responded very positively to the question *"I do not eat any food the caloric value of which I do not know, and which does not fit my caloric intake.,"* or to the question *"When I eat my daily caloric intake, I'm usually resigned to not eating anymore.."* Significantly

TABLE 2 Newly created questionnaire.

1. I am afraid of gaining weight despite my strict diet and training regime.	Always	Often	Rarely	Never
2. I am aware of the caloric value of the food I eat.	Always	Often	Rarely	Never
3. If I eat something outside of my meal plan, I usually add an extra workout.	Always	Often	Rarely	Never
4. I feel comfortable in my body.	Always	Often	Rarely	Never
5. In my strict regime, I treat myself to 1 day of a "cheat day."	Always	Often	Rarely	Never
6. In general, I prefer to prepare my food by myself.	Always	Often	Rarely	Never
7. I want to be slimmer and thus improve my sports performance.	Always	Often	Rarely	Never
8. I am always counting my calorie intake.	Always	Often	Rarely	Never
9. Avoiding foods with a high carbohydrate content (bread, potatoes, rice, etc.) is part of my diet plan.	Always	Often	Rarely	Never
10. I regularly add extra training or exercises.	Always	Often	Rarely	Never
11. I feel anxious if I am not in control of my diet regimen.	Always	Often	Rarely	Never
12. I want to be slimmer and thus improve my physical appearance, I do not care about my sports performance.	Always	Often	Rarely	Never
13. Avoiding foods with sugar content is part of my diet plan.	Always	Often	Rarely	Never
14. My coach thinks I should be slimmer.	Always	Often	Rarely	Never
15. I study in detail the composition and origin of the food on the back of the packaging.	Always	Often	Rarely	Never
16. After mastering the training, I feel stronger and more self-confident.	Always	Often	Rarely	Never
17. When I eat a meal with a high content of carbohydrates, I am afraid of gaining body weight.	Always	Often	Rarely	Never
18. When I have a "cheat day" or I am on an "off season mode," I eat, even when I am no longer hungry or do not have appetite.	Always	Often	Rarely	Never
19. I feel good about my physical "self."	Always	Often	Rarely	Never
20. When I choose my food, its quality is more important to me than its taste.	Always	Often	Rarely	Never
21. If I have to miss my workout, I feel anxious.	Always	Often	Rarely	Never
22. My meal plan allows for foods with sugar content once in a while.	Always	Often	Rarely	Never
23. My coach's opinion affects me in my eating behavior.	Always	Often	Rarely	Never
24. After a "cheat day" or after eating something that is not on my diet plan, I feel sick and have a guilty conscience.	Always	Often	Rarely	Never
25. If I have to choose between hanging out with friends/family and training, I would choose training.	Always	Often	Rarely	Never
26. I feel anxious if I do not have an overview of the caloric values of the food I eat.	Always	Often	Rarely	Never
27. I do not eat any food that contains sugar, even though my meal plan allows it.	Always	Often	Rarely	Never
28. I feel that my diet regime and training are insufficient, and I would like to be slimmer.	Always	Often	Rarely	Never
29. Only through training will I get rid of a bad mood and forget about my problems.	Always	Often	Rarely	Never
30. I do not eat any food whose caloric value I do not know and does not fit my caloric intake.	Always	Often	Rarely	Never
31. When I eat something with less healthy ingredients, I feel uncomfortable.	Always	Often	Rarely	Never
32. Despite my special diet and training regimen, I deliberately reduce my energy intake to be slimmer.	Always	Often	Rarely	Never
33. When I eat my daily caloric intake, I'm usually resigned to not eating anything again.	Always	Often	Rarely	Never
34. I like my body; I nurture and take care of it.	Always	Often	Rarely	Never
35. When I eat a meal with a high content of carbohydrates, I am afraid of gaining body weight.	Always	Often	Rarely	Never
36. I never eat anything if I do not know the exact composition, preparation method or origin of the food.	Always	Often	Rarely	Never
37. I exercise when I am sick or injured.	Always	Often	Rarely	Never
38. My diet regimen consists of a rich variety of foods and ingredients.	Always	Often	Rarely	Never

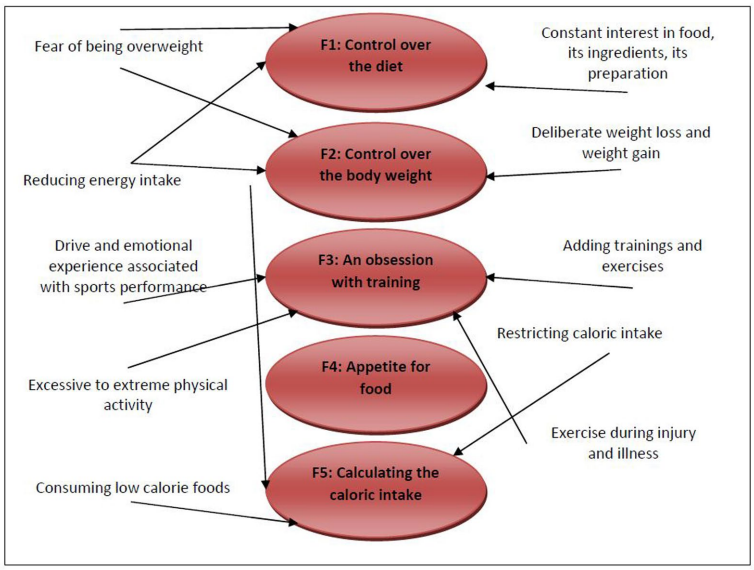

FIGURE 2
Classification of some pathological features under the discovered factors.

frequent were the questions related to monitoring the composition and origin of foods on their packaging, feeling anxious when there is insufficient insight into the caloric values of food and, the compulsive need to know all the information about the food consumed. It can be said that *Control over the diet* defines all the common signs appearing in athletes with disturbed eating behavior.

Control over body weight, a second factor, was found, and under this factor are grouped the questions related mainly to the fear of weight gain and the inner feeling concerning being thinner. Respondents with this factor responded very positively to the question *"I am afraid of gaining body weight despite my strict diet and training regime.,"* and to the question "*I feel that my diet regime and training are insufficient and I would like to be slimmer.*." Furthermore, the respondents reacted very positively to the question "*I want to be slimmer and thus improve my athletic performance.*." This testifies to the aforementioned fact that athletes, in contrast to non-athletes, for whom slimness is often the only goal, associate it with sports performance. So, they take a point of view imitating the equation: "I want to improve my sports performance = I have to lose weight." This fact is manifested when comparing the mutual correlation of the factor and the relevant questions, specifically the question already mentioned above "*I want to be slimmer and thus improve my athletic performance.,*" and the question "*I want to be slimmer and thus improve my physical appearance, I do not care about sports performance.*." The first question concerning sports performance is highly correlated with the factor at 0.60765, while the second question concerning physical appearance shows a completely insignificant negative value of −0.2813 of correlation with the factor. Even in this case, it can be said that the signs of behavior grouped under the factor occur commonly in athletes, and the factor was chosen correctly.

The third factor was named *An Obsession with Training*. Questions related mainly to training are grouped under this factor. Respondents responded very positively to the questions *"I regularly add extra training."* and *"If I have to choose between hanging out with friends/family and training, I will choose training.*." Even in this case, it is clear that the factor reflects common signs of disturbed eating behavior in athletes. Not only do athletes evaluate their body weight through athletic performance, but they also subsequently change their training, which is aimed at athletic performance. They add training, exercise when injured or sick, express all their emotions through training, and make training a priority.

As a fourth factor, we found a factor we named *Appetite for Food*. Under this factor, important questions related to how the athlete manipulates their eating regimen were grouped. For many athletes with disordered eating behaviors, a strict and restrictive eating regimen can be an advantage behind which they can hide their true concerns about their bodies. The second option are athletes who do not have as strict an eating regimen set in the first case, but they still avoid various foods and meals. And it is under this factor that such questions are grouped, and the questions relate to what the athlete's eating regimen allows and whether they are committing a so-called sin, specifically, for example, the question *"In my strict regime, I treat myself to one 'cheat day.'"* Unpleasant feelings after eating, feelings of guilt, and subsequent compensatory behavior are typical of bulimic behavior. Athletes may have a tendency to escape to certain types of food, given that they cannot indulge in them in their strict diet. However, after eating these foods, they subsequently feel guilty, because they violated their eating regimen, and subsequently a chain of typical behaviors and characteristic emotions (guilt, feeling guilty, aggression, etc.) is triggered. Also grouped under this factor are questions regarding the coach's mindset with regard to the athlete's physical appearance and the athlete's own mindset in conjunction with their body. In short, the factor describes how the athlete approaches their eating regimen.

The last, fifth factor, was a factor named *Calculating the Caloric Intake*. Under this factor, as the name suggests, questions related to caloric intake calculation and awareness of the caloric value of food

TABLE 3 Exploratory factor analysis results.

Question	F1	F2	F3	F4	F5
I am afraid of gaining weight despite my strict diet and training regime.	−0.0285	**0.67516**	0.07253	0.0302	0.08335
I am aware of the caloric value of the food I eat.	**0.42261**	0.08845	0.18977	−0.1378	**0.36068**
If I eat something outside of my meal plan, I usually add an extra workout.	0.12354	0.0018	**0.61977**	0.09148	0.32839
In my strict regime, I treat myself to 1 day of a "cheat day."	−0.178	0.05764	0.16755	**0.35833**	0.00787
In general, I prefer to prepare my food by myself.	0.31664	−0.1254	0.15758	−0.2366	0.30822
I want to be slimmer and thus improve my sports performance.	−0.0761	**0.60765**	0.07578	−0.0588	0.01691
I am always counting my calorie intake.	**0.64173**	−0.176	0.16467	0.0889	**0.61676**
Avoiding foods with a high carbohydrate content (bread, potatoes, rice, etc.) is part of my diet plan.	**0.62001**	0.14901	−0.0679	−0.0382	0.1925
I regularly add extra training or exercises.	−0.032	−0.0347	**0.74655**	0.00968	0.27469
I feel anxious if I am not in control of my diet regimen.	**0.61546**	0.19554	0.0805	−0.1486	0.18338
I want to be slimmer and thus improve my physical appearance, I don't care about my sports performance.	0.18771	−0.2819	0.07018	0.04416	−0.0966
Avoiding foods with sugar content is part of my diet plan.	**0.69235**	0.16379	−0.1851	−0.1213	0.20364
My coach thinks I should be slimmer.	−0.0893	**0.432**	0.16659	**0.37645**	0.20082
I study in detail the composition and origin of the food on the back of the packaging.	**0.78773**	−0.2012	0.10199	−0.0407	0.05464
After mastering the training, I feel stronger and more self-confident.	0.05875	0.15059	−0.6223	0.3349	0.16131
When I eat a meal with a high content of carbohydrates, I am afraid of gaining body weight.	0.17791	**0.57765**	0.12283	−0.2976	−0.0284
When I have a "cheat day" or I am on an "off season mode," I eat, even when I am no longer hungry or don't have appetite.	0.04132	0.18151	0.10764	−0.6029	0.12464
When I choose my food, its quality is more important to me than its taste.	**0.70602**	−0.2601	0.02179	0.00464	−0.0054
If I have to miss my workout, I feel anxious.	0.26869	−0.0118	0.31489	0.13638	−0.1108
My meal plan allows for foods with sugar content once in a while.	0.02571	−0.2285	−0.0895	**0.71044**	0.05346
My coach's opinion affects me in my eating behaviour.	0.26281	0.33764	0.32878	0.19397	0.01947
After a "cheat day" or after eating something that is not on my diet plan, I feel sick and have a guilty conscience.	0.3245	**0.4673**	0.05311	−0.1339	−0.0145
If I have to choose between hanging out with friends/family and training, I would choose training.	−0.2111	0.17431	**0.70636**	0.15571	−0.0405
I feel anxious if I don't have an overview of the caloric values of the food I eat.	**0.76682**	0.09958	0.03205	−0.0477	0.24645
I don't eat any food that contains sugar, even though my meal plan allows it.	**0.71965**	0.03306	−0.0855	0.21787	−0.1669
I feel that my diet regime and training are insufficient, and I would like to be slimmer.	0.07346	**0.67515**	0.04247	−0.0798	−0.2552
Only through training will I get rid of a bad mood and forget about my problems.	−0.0994	0.02593	**0.35571**	−0.15	0.02581
I do not eat any food whose caloric value I do not know and does not fit my caloric intake.	**0.95453**	−0.191	−0.0467	0.1036	0.21382
When I eat something with less healthy ingredients, I feel uncomfortable.	**0.43364**	0.14112	−0.0176	**0.43456**	−0.1075
Despite my special diet and training regimen, I deliberately reduce my energy intake to be slimmer.	**0.51999**	0.26496	0.00764	−0.1922	−0.1842
When I eat my daily caloric intake, I'm usually resigned to not eating anything again.	**0.85938**	0.03889	−0.0914	−0.2136	0.01943
I like my body; I nurture and take care of it.	0.15525	0.28888	−0.0567	**0.48155**	0.0718
When I eat a meal with a high content of carbohydrates, I am afraid of gaining body weight.	0.20255	**0.61078**	−0.2361	0.09558	−0.3003
I never eat anything if I don't know the exact composition, preparation method or origin of the food.	**0.77575**	0.0326	−0.0967	0.02187	0.01445
I exercise when I am sick or injured.	0.11773	0.11263	**0.51471**	0.06772	−0.0263
My diet regimen consists of a rich variety of foods and ingredients.	**0.69025**	0.09148	−0.1946	0.20043	**0.42186**

Bold values means the correlation coefficients for selected questions grouped under each factor.

are grouped. Calculating caloric intake and knowing caloric values is not at all unusual for competitive athletes, many athletes even create their own meal plan and thus they have to work with individual values. However, what is important is to what extent it is the norm and when counting caloric intake can become a pathology.

5.1. Point score of the respondents

As already mentioned above, compared to the original EAT-26 questionnaire, the point score was adjusted, and its cut-off value was set at 57 points and above. Of the respondents, 33%, i.e., 33 out of a possible 100, achieved the specified or higher value.

Respondents with a point score of 57 and above were found in every sport tested. Of the 33 respondents reaching the point limit, 6% of respondents were in aerobics, 24% of respondents in gymnastics, 15% of respondents in professional dance, 27% of respondents in figure skating, and 27% of respondents were among bodybuilding/fitness. The largest number of respondents with a point score of 57 and above was found in figure skating and bodybuilding/fitness, where nine respondents achieved a point score in both sports. The least was found in aerobics, where only two respondents achieved the point score. Among all 33 respondents scoring 57 and above, there were seven males and 26 females, with all seven males engaged in the same sport, bodybuilding/fitness.

From the group of respondents achieving a point score of 57 or higher, the youngest respondent was 18 years old, while the oldest was 26 years old. The rest of the respondents achieving a point score of 57 and higher were most often between 20 and 23 years old, which can be characterized as a typical age for a peak career in most aesthetic sports.

5.2. Point score by sport branch

Subsequently, individual scores were also compared according to the sports sector. One respondent could get a maximum number of points 108. So, all 20 respondents from the same sport could reach a limit of 2,160 points. In total, all respondents could get a total of 10,800 points. The total number of points of all respondents reached roughly half of the possible points obtained; all respondents together obtained 5,026 points. Of these, the largest number of points was obtained by respondents from bodybuilding and fitness, who together obtained 1,175 points. Bodybuilding and fitness are very specific because of their diet regimens. Athletes often go through different phases of their diets and their preparations, shock the body by starving or, on the contrary, by overeating, and last but not least, more than anyone else, they adhere to a strict and exact diet plan. There exist several studies that describe the occurrence of eating disorders in this specific sport branch, for example, anorexia nervosa is often described in female competitors in the category of bikini fitness. The next highest possible number of points obtained belonged to gymnastics and figure skating, where the respondents from a gymnastics background received a combined 1,069 points, and the respondents from a figure skating background received a combined 1,006 points. Both sports are very characteristic for their technical elements, where lower body weight is a great advantage. Athletes very often reduce their body weight in order to include the most complicated technical elements in their sets. Gymnastics is also a very common sport, where the occurrence of eating disorders has already been described several times. Subsequently, aerobics was ranked after gymnastics and figure skating, where all respondents together scored 951 points. Aerobics can be very similar to gymnastics in some ways and is also very typical for its technical elements where a lower body weight can be an advantage. At the same time, athletes are evaluated by so-called artistic judges, who evaluate the athlete's appearance and demeanor. The least number of points was awarded to dancing, where all respondents together scored 825 points. The difference between bodybuilding/fitness and dancing is very interesting, where the difference is up to 42% (Table 4).

TABLE 4 Number of points achieved in individual sports branches.

Sport branch	Number of points	Number of respondents	The average number of points
Bodybuilding/fitness	1,175	20	59
Gymnastics	1,069	20	53
Figure skating	1,006	20	50
Aerobics	951	20	48
Dancing	825	20	41

Understandably, respondents from the bodybuilding and fitness sports branches scored the most points on average, as they were the only ones who exceeded the threshold of 57 points on average. Respondents from the gymnastics, figure skating, and aerobics industries stayed just below the threshold of 57 points. The respondents from the dancing area did the best in the average number of points. From the researched group, athletes from the bodybuilding and fitness sports sectors had a much more frequent tendency to exceed the specified point limit and it can be said that they have a much greater tendency toward disordered eating behavior than other respondents from other sports sectors. However, it is not possible to carry out a detailed analysis of all variables that would show which of the sports mentioned above has the greatest tendency to the occurrence of disturbed eating behavior or eating disorders, due to the small number of respondents in each sports group.

Among all 33 respondents scoring 57 and above, there were seven males and 26 females, with all seven males involved in the same sport, namely bodybuilding/fitness.

6. Discussion

Factor analysis discovered five common significant factors: Control over the diet, Control over the body weight, An obsession with training, Appetite for food, and Calculating the caloric intake. All the factors found can be considered common characteristics for the eating and training regimen of athletes, as well as areas that can be transferred to the level of pathological behavior. It is therefore necessary to respect these factors as part of the training process, but at the same time take their degree into consideration.

de Fortes et al. (2016) verified in their study the psychometric properties of the Disordered Eating in Sports Scale (DES) created by them using 1,338 Brazilian athletes and compared it with the EAT-26

test. They also state that the EAT-26 test does not respect the behavior and needs of the athletes. Doninger et al. (2005) verified the psychometric properties of the EAT-26 test in athletes on a group of 207 female athletes. The factor analysis resulted in five factors: Drive for Thinness, Food Preoccupation, Others' Perceptions, Purging Behavior, and Dieting Behavior. These factors have some elements in common with the factors found in our study.

Martinsen et al. (2010) examined eating behavior in adolescent elite athletes and compared it to a non-athlete control group. Their study entitled *"Dieting to win or to be thin?"* describes dietary behavior as the most important factor in athletes. The authors of the study consider diets and dietary behavior to be the most typical feature of elite athletes, and at the same time describe a very thin line between dietary behavior used to improve sports performance and eventual success, and dietary behavior that can very easily turn into a pathological level. At the same time, this study confirms the appropriateness of the selection of some questionnaire questions regarding dietary behavior. For example, one of the many questions might be a system of questions: "*Avoiding foods with sugar content is part of my diet plan," "My meal plan allows for foods with sugar content once in a while," "I do not eat any food that contains sugar, even though my meal plan allows it.*" These example questions clearly highlight the fact mentioned above; the first question is aimed at mapping the athlete's eating regimen, the second question is simultaneously based on the first question, however it expands the evaluator's overview of how strict the athlete's eating regimen is, and finally the third and last question can indicate whether the eating behavior is a norm or a pathology. For example, 58 respondents answered *"never"* to the last question regarding whether or not an athlete allows himself to eat food containing sugar. These results continue to confirm the claim that the overall point score should only serve as an informative one and the individual answers of the respondents should subsequently be analyzed in detail despite the fact that the respondent did not reach the given point score limit. In other words, "only" 33 respondents reached the threshold of 57 points and above, but as can be seen, far more respondents avoid sugary foods, even if they do not have to. Another study confirming the factors representing part of the training process and risk was carried out by Francisco et al. (2012) in aesthetic sportswomen, specifically in elite dancers and gymnasts. The study dealt with the investigation of specific characteristics in the dance and gymnastics environment. The results of the study showed that the aforementioned characteristics are also risk factors for the emergence of disturbed eating behavior and the development of eating disorders. Specifically, the results showed that 58% of elite dancers and gymnasts exhibited risk factors, while in 29% these were sport-specific. This fact underlines not only the results of this study, when the characteristic features of sport are also referred to as risk factors, but also the risk context of all aesthetic sports. However, the question remains how to prevent the tendency to follow the rules of the given sports from turning into a risk of pathological behavior. From the theoretical findings, it follows that the biggest influence is attributed to the coaches, the increasing demands of the given sport, and the competition. In other words, facts that are difficult to eliminate. However, it is possible to intervene in the area of the athlete's perception of these influences and increase his resistance to them, which is implemented within the framework of an individual approach to each athlete and close cooperation between a coach and a sports psychologist.

Sundgot-Borgen and Garthe (2011) consider the extreme methods of weight reduction used in sports with weight categories to be risky for the emergence of pathological eating behavior and describe preventive strategies that could prevent the current situation, including the development of sports education programs for coaches and athletes themselves and adjustments to sports rules in some sports.

There are also suggestions by researchers that modern technologies, including apps aimed at controlling energy intake and monitoring physical activity, may promote the development of pathological eating behavior, as confirmed by studies such as Simpson and Mazzeo (2017). In contrast, the study by Hahn et al. (2021) did not confirm this.

Piepiora et al. (2018) looked at the relationship between body composition and eating behavior in female wrestlers, but no relationship was found in their study. Piepiora et al. (2017) also investigated the relationship between personality characteristics as measured by the NEO-FFI and eating behavior in young female wrestlers and tennis and volleyball players, but no relationship was found.

The coach's approach to their client therefore plays a significant role. In many cases, the coach is the closest person to the athlete, with whom the athlete often spends the most time. The coach's influence is also indicated by the answers to the question *"Does my coach's opinion influence me in my eating behavior."* in our study, where only 11 respondents gave a completely negative answer of "never." More than half of the respondents answered "always" (23 respondents) and "often" (32 respondents), the neutral answer "rarely" was subsequently chosen by 34 respondents. In some cases of more sensitive and introverted individuals, the coach's attitude and opinion can be the decisive factor in the emergence of pathological eating behavior.

The main results of this research investigation therefore brought positive findings, namely that the newly created questionnaire is applicable to a group of competitive athletes and can fully reflect the common characteristics of an athlete's regimen. However, it does not provide a solution to the problem that lies in the coaching team's approach to the athlete and in the athlete's behavior under the action of environmental influences. It is important to ensure high-quality and professional conditions for athletes, an individual approach to the athlete, and full care in all spheres of sports preparation (training care, psychological care, and health care).

The weakness of this and other verbal methods is the distortion of respondents' answers, when many of them associate a truthful answer with the fear of confessing to pathological eating behavior. Therefore, respondents subsequently choose the answers they think are correct, regardless of whether they have or perceive a problem in that area. Defense mechanisms also play a role; typically it is rationalization, when the athlete unintentionally answers the questionnaire differently to how they behaves in reality.

The phenomenon of pathological eating behavior in sports does not have a definitive solution, but for professionals working in this area, it is an important task to try to act preventively and to solve any pathological conditions that may arise as soon as possible in order to preserve the health of the athlete. It is also possible that they may encounter an ethical dilemma, where they will have to balance the current success of the athlete against their health.

7. Conclusion

The EAT-26 questionnaire was first analyzed in detail and reworked into a form that could be applied to a group of competitive athletes. The main goal of the study was to confirm the correctness and appropriateness of the newly chosen questions. Factor analysis discovered five strong common factors that replicate characteristics that athletes are very familiar with from their sports training. In addition to the factor analysis, an analysis of the respondents' point scores was subsequently performed. The amount of the point score helps to determine whether the individual may have disturbed eating behavior or an eating disorder. However, the point score should only serve as a guideline, and attention should also be paid to individuals who did not reach the specified point score limit. Eating disorders are a very intimate topic and their diagnosis can be very difficult. Diagnostics in the field of performance sports can then be particularly demanding. Therefore, even the most banal symptoms should be paid attention to. The athlete's body and his physical and mental health represent an important key to success. It should also be approached in such a spirit, not as a human machine. We plan to follow up on our research with further studies using a larger number of respondents, or the utilization of the questionnaire in other sports groups as well, not only in aesthetic sports. This is a pilot study representing the first step in the overall validation process of the new method.

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.

Ethics statement

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

Author contributions

DS and TB conceived and designed the research. TB performed the research and analyzed the data. DS interpreted the results. BP drafted and edited manuscript. All authors critically revised manuscript and approved the final version of the manuscript.

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.

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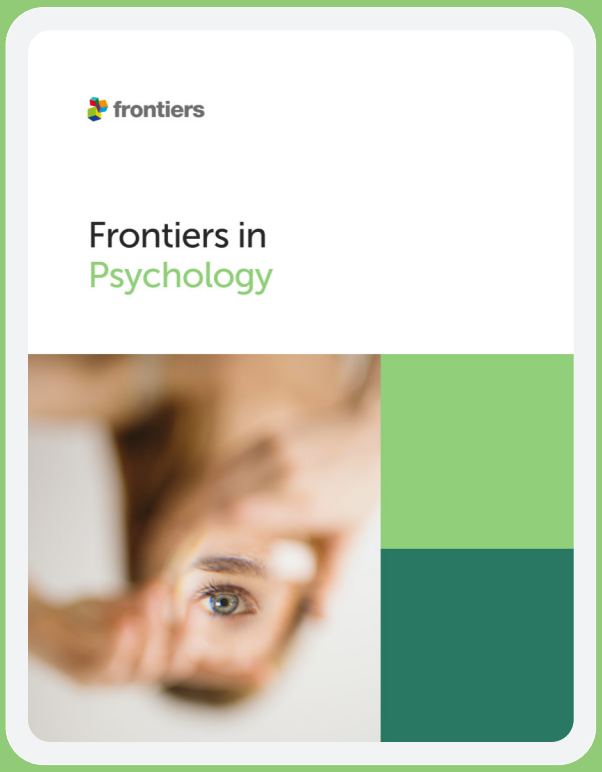

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