



# Effects of Chronological Age, Relative Age, and Maturation Status on Accumulated Training Load and Perceived Exertion in Young Sub-Elite Football Players

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The aims of this study were 1) to analyze the influence of chronological age, relative age, and biological maturation on accumulated training load and perceived exertion in young sub-elite football players and 2) to understand the interaction effects amongst age grouping, maturation status, and birth quartiles on accumulated training load and perceived exertion in this target population. A 6-week period (18 training sessions and 324 observation cases) concerning 60 young male sub-elite football players grouped into relative age (Q1 to Q4), age group (U15, U17, and U19), and maturation status (Pre-peak height velocity (PHV), Mid-PHV, and Post-PHV) was established. External training load data were collected using 18 Hz global positioning system technology (GPS), heart-rate measures by a 1 Hz short-range telemetry system, and perceived exertion with total quality recovery (TQR) and rating of perceived exertion (RPE). U17 players and U15 players were 2.35 (95% CI: 1.25–4.51) and 1.60 (95% CI: 0.19–4.33) times more likely to pertain to Q1 and Q3, respectively. A negative magnitude for odds ratio was found in all four quartile comparisons within maturation status (95% CI: 6.72–0.64), except for Mid-PHV on Q2 (95% CI: 0.19–4.33). Between- and within-subject analysis reported significant differences in all variables on age group comparison measures ( $F = 0.439$  to  $26.636$ ,  $p = 0.000$  to  $0.019$ ,  $\eta^2 = 0.003$ – $0.037$ ), except for dynamic stress load (DSL). Between-subject analysis on maturity status comparison demonstrated significant differences for all training load measures ( $F = 6.593$  to  $14.424$ ,  $p = 0.000$  to  $0.037$ ,  $\eta^2 = 0.020$ – $0.092$ ). Interaction effects were found for age group x maturity band x relative age ( $\Lambda$  Pillai's =  $0.391$ ,  $\Lambda$  Wilk's =  $0.609$ ,  $F = 11.385$ ,  $p = 0.000$ ,  $\eta^2 = 0.391$ ) and maturity band x relative age ( $\Lambda$  Pillai's =  $0.252$ ,  $\Lambda$  Wilk's =  $0.769$ ,  $F = 0.955$ ,  $p = 0.004$ ,  $\eta^2 = 0.112$ ). Current research has confirmed the effects of chronological age, relative age, and biological maturation on accumulated training load. Perceived exertion does not seem to show any differences concerning age group or maturity status. Evidence should be helpful for professionals to optimize the training process and young football players' performance.

**Keywords:** youth, growth, workload, GPS, RPE, heart rate

## INTRODUCTION

Monitoring accumulated training load has become a research hot topic in youth football environments (Teixeira et al., 2021a; Miguel et al., 2021). Electronic performance and tracking systems (EPTS) provide affordable and indispensable time-motion technologies for assessing valid training load measures (Linke et al., 2018). The research-practice prominence is due to numerous factors, among which the literature reports practical applicability in the field of strength and conditioning (Cumming et al., 2017), talent identification (Sarmiento et al., 2018a), injury prevention (Coppalle et al., 2019; Boullosa et al., 2020), training task design (Coutinho et al., 2017, 2020), and control and performance analysis (Sarmiento et al., 2018b; Zurutuza et al., 2017). For several years, literature has reported widely on load terminology such as work rate (O'Donoghue, 2004; Carling et al., 2008), workload (Bowen et al., 2017; Williams et al., 2017; Gabbett et al., 2019), and training load (Impellizzeri et al., 2005; Bourdon et al., 2017; Vanrenterghem et al., 2017). These assumptions are based on a linear perspective where the smallest changes in the system input determine proportional and measurable changes in the output (Vanrenterghem et al., 2017; Impellizzeri et al., 2019). Therefore, the training load concept has been developed by setting up athlete monitoring as a linear system using cumulative effect as a key guidance (Coutts et al., 2017). Cumulative effect is a primary factor to be considered on long-term athletic preparation (Lloyd & Oliver, 2012; Sarmiento et al., 2018a).

Typical accumulated training load has already been evaluated in young elite and sub-elite football players (Wrigley et al., 2012; Abade et al., 2014; Coutinho et al., 2015; Teixeira et al., 2021b). An age-related influence was reported for both competitive levels; however, some differences are verified in other independent and conditioned variables, such as playing position and periodization structure. Abade et al. (2014) reported higher total distances covered in under-17 (U17), followed by under-19 (U19), and under-15 (U15) elite football players. Authors also reported lower total and relative body impacts in U15 players. Coutinho et al. (2015) reported a higher total distance covered, body impacts, and high-intensity running in U19 post-match training sessions. Wrigley et al. (2012) reported a higher total weekly training load for under-18 (U18) players. In sub-elite football training, Teixeira et al. (2021b) reported interaction effects between age group, training day, weekly micro-cycle, and playing position for deceleration and between training day, weekly micro-cycle, and age for total covered distance. Also, Teixeira's study reported minimum effect for playing position on the weekly training load. The weekly accumulated training load varied according to age group, training day, inter-week, and playing position (Wrigley et al., 2012; Abade et al., 2014; Coutinho et al., 2015; Teixeira et al., 2021b). Nonetheless, the playing position seems to be negligible in relation to age and periodization structure (Teixeira et al., 2021b). Recently, a systematic review summarized the studies which have examined external and internal training intensity monitoring;

however, the influence of maturity and relative age on accumulated training load and perceived exertion has not been described in any of the available studies (Oliveira et al., 2021).

Relative age and biological maturation were independent and non-modifiable factors that should be considered in player selection, as well as in monitoring and assessment performance in youth football (Cumming et al., 2017; Lovell et al., 2019; Hill et al., 2020). Biological maturation refers to progress towards the adult or mature state defined by status, timing, and tempo (Malina et al., 2015, 2019). According to the maturation-matching assumptions reported by Malina et al. (2019), maturation status, timing, and tempo are distinct concepts: 1) maturation status is the specific maturation stage at the observation time, expressed for instance as skeletal age and stage of pubic hair development; 2) maturation timing is the age at the specific maturational event occurrence, expressed as age at peak height velocity (PHV); and 3) maturation tempo reports the maturation progress in a specific system. Otherwise, relative age refers to a player's chronological age regarding the competitive cohort and is determined by quartile birth and the competition age-group cohort (Patel et al., 2019, 2020; Hill et al., 2020). Previous studies have demonstrated the influence of relative age, maturation, and anthropometry on physical performance characteristics in elite youth football (Patel et al., 2019, 2020). This evidence seems to be particularly relevant for high-intensity variables, such as sprinting or acceleration (Edwards et al., 2021; Kelly et al., 2021), as well as perceived exertion (Cumming et al., 2018; Hill et al., 2021). Relative age effect (RAE) has been demonstrated within different elite youth football academies (Skorski et al., 2016; Rubajczyk and Rokita, 2018; Hill et al., 2020). Hence, a player selection bias is a consequence of RAE, due to the inter- and intra-variability inherent in biological maturation (Simmons and Paull, 2001; Saavedra-García et al., 2019; Sarmiento et al., 2018b). Indeed, differences amongst maturity status and relative age have been identified in previous investigations, along with a considerable variation in timing and rate for physical and biological maturation (Johnson et al., 2017; Towson et al., 2017). In football, RAE can affect the beginning of a senior career in football with a large over-representation of players born close to the end of the calendar year (Lupo et al., 2019a). Thus, identifying player advances and delays in growth and maturation plays a key role when evaluating player fitness, considering the role of development stages (Cumming, 2018; Ryan et al., 2018).

The analysis of the dependency amongst training load variations and maturational variables has been reported in the literature on elite youth football players (Nobari et al., 2021a, 2021b; Salter et al., 2021). The survey reports the influence of accumulated training load and maturation status in the differences observed across the season (Nobari et al., 2021a). As well known, no studies have included maturational and birth quartile variables to monitor accumulated training load and perceived exertion in sub-elite youth football. Moreover, training load quantification often uses the age-grouping

**TABLE 1** | Description baseline characteristics of participants.

Group	Age (y)	Relative age	Maturity offset	Height (m)	Weight (kg)	BMI (kg/m <sup>2</sup> )	Sitting height (cm)	PHV (cm)	Experience (y)
U15 (n = 102)	13.28 ± 0.49	0.25 ± 0.17	-0.42 ± 0.76	1.69 ± 0.78	55.67 ± 9.41	19.29 ± 1.99	81.96 ± 5.78	14.18 ± 0.80	4.82 ± 0.90
U17 (n = 99)	15.39 ± 0.51	0.25 ± 0.17	2.02 ± 1.09	1.76 ± 0.48	64.28 ± 6.61	20.68 ± 1.79	92.02 ± 7.61	13.90 ± 1.09	6.64 ± 1.65
U19 (n = 120)	17.29 ± 0.55	0.24 ± 0.20	2.23 ± 1.49	1.76 ± 0.70	68.90 ± 8.39	22.11 ± 1.50	90.73 ± 8.06	14.46 ± 1.87	8.81 ± 1.70
Pre-PHV (n = 52)	13.08 ± 0.39	0.22 ± 0.16	-0.98 ± 0.48	1.68 ± 0.07	56.27 ± 8.63	19.76 ± 1.95	78.08 ± 3.98	14.52 ± 0.66	3.53 ± 0.29
Mid-PHV (n = 65)	14.38 ± 1.66	0.20 ± 0.17	-0.02 ± 0.31	1.73 ± 0.10	60.20 ± 11.73	19.81 ± 2.10	87.54 ± 7.91	13.31 ± 1.83	4.53 ± 1.23
Post-PHV (n = 207)	15.99 ± 1.40	0.27 ± 0.18	2.34 ± 1.17	1.75 ± 0.06	64.75 ± 8.93	21.08 ± 2.06	91.21 ± 7.43	14.40 ± 1.26	9.23 ± 1.36
ALL (n = 324)	15.19 ± 1.75	0.25 ± 0.18	1.33 ± 1.67	1.74 ± 0.08	62.48 ± 10.03	20.61 ± 2.14	88.36 ± 8.51	14.20 ± 1.39	6.76 ± 1.42

PHV, peak height velocity.

approach instead of bio-banding strategies to compare inter- and intra-individual differences in weekly accumulated training load (Cumming et al., 2017). Previous studies have analyzed the influence of chronological age, relative age, and maturation from standardized physical fitness assessment (Clemente et al., 2019; Nobari et al., 2021a, 2021b; Salter et al., 2021), however this does not include the accumulative outcomes of external and internal training intensity (Oliveira et al., 202; Otte et al., 2019). Upon that, the aims of this study were to 1) to analyze the influence of chronological age, relative age, and biological maturation on accumulated training load and perceived exertion in sub-elite young football players and 2) to understand the interaction effects amongst age grouping, maturation status, and birth quartiles on accumulated training load and perceived exertion in this target population. Based on the relevant literature, we hypothesized that accumulated training load and perceived exertion in young football players will be influenced by advanced growth, relative age, and biological maturation (Clemente et al., 2019; Nobari et al., 2021a, 2021b).

## METHODS

### Participants

Participants were sampled from a sub-elite Portuguese youth football academy certified via a zero to four star scale by the Portuguese Football Federation (Santos et al., 2021). A total of 60 male football players was included in this study using an observational, cross-sectional, and convenience sample. **Table 1** shows the description baseline characteristics of participants according to age group (i.e., U15, U17, and U19 players) and maturation status (i.e., Pre-, Mid-, and Post-PHV).

All participants were notified about the study's aims and risks comprised in the research. The study only included players that signed the informed consent, which was conducted according to the ethical standards of the Declaration of Helsinki. The experimental approach was approved and followed by the local Ethical Committee from University of Trás-os-Montes e Alto Douro (3379-5002PA67807).

### Experimental Approach

The weekly training load was continuously monitored in the three age groups during the first month of the 2019–2020 competitive

season. The training data corresponded to a 6-week period (18 training sessions and 324 observation cases). The eligibility criteria for individual data sets considered a competitive one-game week schedule and complete full training sessions. The microcycle was comprised of three training sessions per week (~90 min). The match data were not included in the analysis. The training days were classified as “match day minus format” (MD): MD-3 (Tuesday), MD-2 (Wednesday), and MD-1 (Friday). Training sessions had, on average, 18 players. All age groups trained on an outdoor pitch of official dimensions (FIFA standard; 100 × 70 m). The training sessions were performed on synthetic turf pitches, between 10:00 AM to 08:00 PM and similar environment conditions (14–20°C; relative humidity 52–66%).

The sampled training sessions were categorized according to a specific focus following the discussion with the coach staff. All sampled training sessions started with a standard warm-up with low-intensity running, dynamic stretching for main locomotive lower limb muscles, technical actions, and ball possession. The weekly training overview presented a potential variable between categories, such as different training modes with emphasis in game-based situations, sport-specific skills, and football-specific exercises (Abade et al., 2014; Zurutuza et al., 2017).

### Procedures

Outfield players were monitored using a portable GPS throughout the whole training session (STATSports Apex<sup>®</sup>, Northern Ireland). The GPS device provided raw position velocity and distance at 18 Hz sampling frequencies, including an accelerometer (100 Hz), magnetometer (10 Hz), and gyroscope (100 Hz). Each player used the micro-technology inside a mini pocket of a custom-made vest supplied by the manufacturer, which was placed on the upper back between both scapulae. All devices were activated 30 min before the training data collection to allow an acceptable clear reception of the satellite signal. Respecting the optimal signal to the measurement of human movement, the match data considered eight available satellite signals as the minimum for the observations (Beato et al., 2018). Validity and reliability of global navigation satellite systems (GNSS), such as GPS tracking, have been well established in the literature (Beato et al., 2018; Nikolaidis et al., 2018; Whitehead et al., 2018). Current variables and thresholds should consider a small

error of around 1–2% reported in the 10 Hz STATSports Apex<sup>®</sup> units (Beato et al., 2018).

## Anthropometry, Relative Age, and Maturity Status

Anthropometric measures were obtained using standard guidelines (Duncan et al., 2019). Players' height (m), weight (kg), chronological age (years), sitting height (cm), and experience level (years) were collected at each measurement point. Body mass index (BMI) was calculated by dividing the weight by the square of the height ( $\text{kg/m}^2$ ). Relative age (a.u.) was calculated as the difference between the player's birthdate and the cut-off date (31 August) divided by the number of days within a year (i.e., 365 days) (Hill et al., 2020). Birth quartiles dates were categorized into birth quartiles (Q) within each age group as: Q1–September to November; Q2–December to February, Q3–March to May, and Q4–June to August (Patel et al., 2019; Hill et al., 2020). Maturity status was based on a predictive Mirwald's equation (Mirwald et al., 2002) using chronological age, standing height, sitting height, and body mass, as previously established for youth team sports environments (Coutinho et al., 2020; Arede et al., 2021). Sampled players were grouped into three maturity bands based on the predicted adult height (PHV): <88% (Pre-PHV); 88–95% (Mid-PHV), and >95% (Post-PHV) of the predicted adult stature (Cumming et al., 2017). Maturity timing was estimated by z scores: higher than 0.5 (early status); between -0.5 and +0.5 (average maturity timing; this means the players were considered as average in their maturity stages); and below -0.5 (late maturity timing) (Bradley et al., 2019; Arede et al., 2021).

## External Training Load Measures

External training load was obtained through time-motion data: total distance (TD) covered (m), average speed (AvS), maximal running speed (MRS) ( $\text{ms}^{-1}$ ), relative high-speed running (rHSR) distance (m), high metabolic load distance (HMLD) (m), sprinting (SPR) distance (m), dynamic stress load (DSL) (a.u.), number of accelerations (ACC), and number of decelerations (DEC). The GPS software provided information only about the locomotor categories above  $19.8 \text{ km h}^{-1}$ : rHSR ( $19.8\text{--}25.1 \text{ km h}^{-1}$ ) and SPR ( $>25.1 \text{ km h}^{-1}$ ). Sprints were measured by number and average sprint distance (m). HMLD is a metabolic variable defined as the distance, expressed in meters, covered by a player when the metabolic power exceeds  $25.5 \text{ W kg}^{-1}$ . HMLD variables include all high-speed running and accelerations and decelerations above  $3 \text{ m s}^{-2}$  (Beato et al., 2019; Gómez-Carmona et al., 2020). Both acceleration variables (ACC/DEC) considered the movements in the maximum intensity zone ( $>3 \text{ m s}^{-2}$  and  $<3 \text{ m s}^{-2}$ , respectively). DSL was evaluated by a 100 Hz tri-axial accelerometer integrated into the GPS devices by measuring the sum of the accelerations in the three orthogonal axes of movement (X, Y, and Z planes), so as to measure a composite magnitude vector (expressed as G force) (Beato et al., 2019).

The high-intensity activity thresholds were adapted from previous studies (Teixeira et al., 2021a; Miguel et al., 2021). The GPS variables were recorded for each individual player.

Individual training data were eliminated from the analysis whenever players left the training before the end of the session due to erroneous data collection, injury, training absence, or early withdrawal (the exclusion criteria resulted in the elimination of 36 observation cases).

## Heart Rate-Based Measures

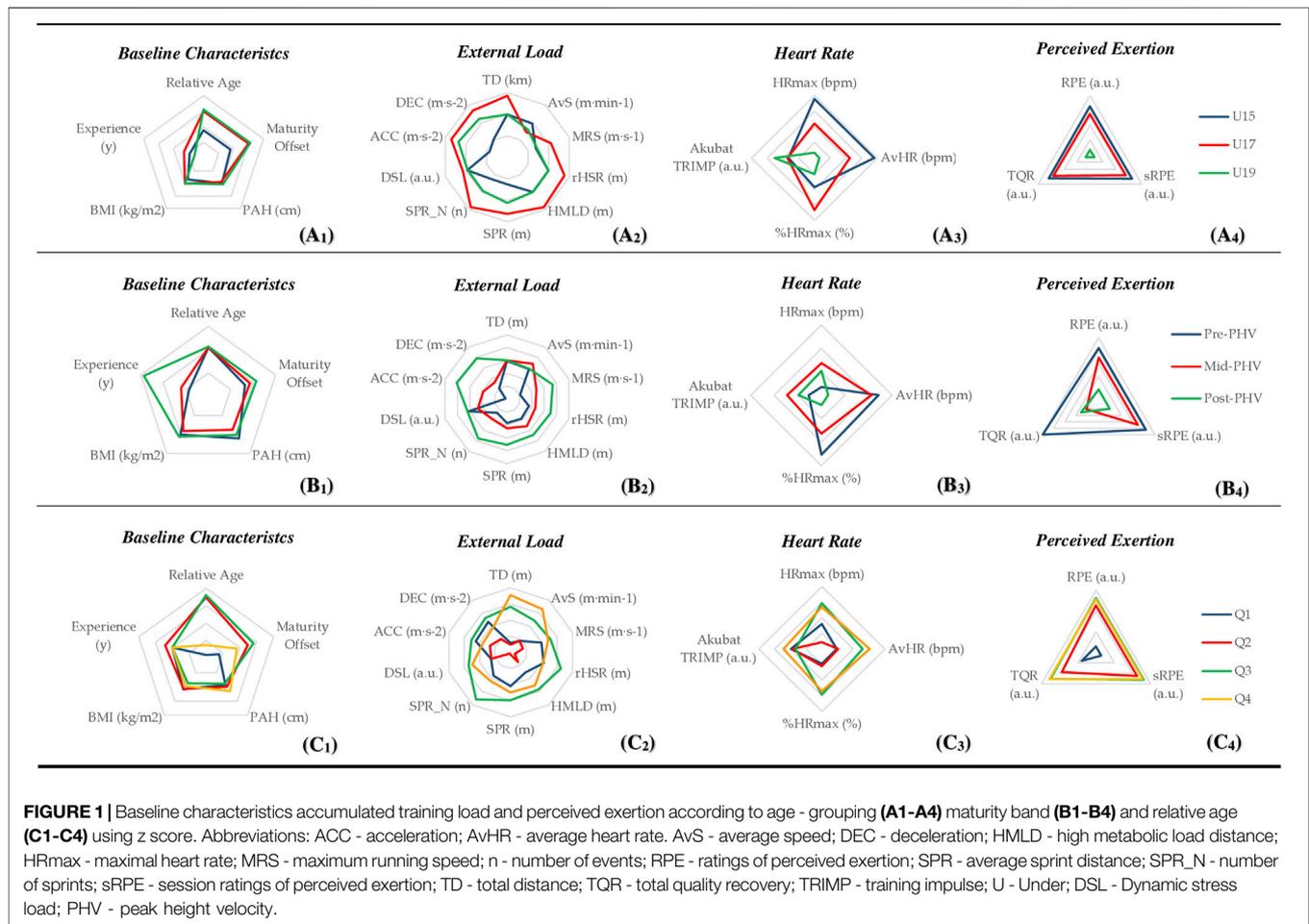
Heart rate was recorded by 1 Hz short-range telemetry system GARMIM TM HR band (International Inc., Olathe, KS, USA). Maximum heart rate ( $\text{HR}_{\text{max}}$ ), average heart rate (AvHR), and percentage of  $\text{HR}_{\text{max}}$  ( $\%\text{HR}_{\text{max}}$ ) values were considered for analysis (Branquinho et al., 2020, 2021). Training impulse was obtained by Akubat TRIMP (Akubat et al., 2012, 2014), reporting a team TRIMP, whose equation is based on individual training load from players' iTRIMP; however, Akubat TRIMP was calculated as: training duration  $\times 0.2053e^{3.5179x}$ . Where e is the Napierian logarithms, 3.5179 is the e exponent, and x is the  $\text{HR}_{\text{ratio}}$  (Akubat et al., 2012).  $\text{HR}_{\text{ratio}}$  is the same in Banisters TRIMP (Teixeira et al., 2021a),  $\text{HR}_{\text{max}}$  was obtained by the Yo intermittent recovery test level 1 (YYIR1) (Bangsbo et al., 2008; Hung et al., 2020).

## Perceived Exertion

Perceived exertion was measured using the 15-point Portuguese Borg Rating of Perceived Exertion 6–20 Scale (Borg RPE 6–20) (Cabral et al., 2020). The sRPE was obtained by multiplying total duration of training sessions for each individual's RPE score (sRPE = RPE  $\times$  session duration) following a scale from 6 to 20 (Haddad et al., 2017). To monitor recovery, each player was asked to report the TQR score on a scale from 6 to 20. This scale was proposed by Kenttä and Hassmén (1998) to measure athletes' recovery perceptions. Previous research included the TQR score examining perceived stress and fatigue in youth football (Brink et al., 2010; Clemente et al., 2019; Teixeira et al., 2021b). RPE and TQR were collected individually at approximately 30 min after and before each training session, respectively. Players were preemptively familiarized with the procedures, and perceived data were collected using a Microsoft Excel<sup>®</sup> spreadsheet (Microsoft Corporation, U.S.).

## Statistical Analysis

Robust estimates of 95% confidence interval (CI) and heteroscedasticity were calculated by a bootstrapping technique (randomly 1,000 bootstrap samples) (Beato and Drust, 2021; Maughan et al., 2021). Birth quartile distribution according to group and maturation band were calculated by counts (n), frequencies (%), and odds ratio (OR) (Patel et al., 2019; Hill et al., 2020). Z score was computed to compare accumulated training load measures and perceived measures (Gallo et al., 2016; Cumming et al., 2017). A one-way analysis of variance (ANOVA) was used to identify differences between age groups and maturation bands. A repeated-measures multivariate analysis of variance (MANOVA) was applied to analyze within-subject changes and interaction effects (age group  $\times$  maturity band  $\times$  relative age) (Charness et al., 2012; Barbosa et al., 2016). The sample size was calculated with G\*Power, Version 3.1.5.1 (Institut für Experimentelle Psychologie, Düsseldorf, Germany), using an effect size  $\beta$  of 0.4, an  $\alpha$  of 0.05, and a power of 0.8 ( $1-\beta$ ) (Abade et al., 2014). For ANOVA



repeated-measures within-between interaction, the total sample size computed was 15 subjects. For MANOVA repeated-measures within-between interaction, the total sample size computed was 91. The number of groups and measures considered were 3 and 17, respectively. When a significant difference occurred, Bonferroni post-hoc tests were used to identify localized effects. Games-Howell post-hoc tests were applied if variances were not homogeneous. The effect size eta square ( $\eta^2$ ) was computed and interpreted as: 1) without effect if  $0 < \eta^2 \leq 0.04$ ; 2) minimum if  $0.04 < \eta^2 \leq 0.25$ ; 3) moderate if  $0.25 < \eta^2 \leq 0.64$ ; and 4) strong if  $\eta^2 > 0.64$  (Ferguson, 2009). Standardized effect sizes (ES) were calculated with Cohen's *d* for pairwise comparison, classified as: 0–0.2, trivial; 0–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; 2.0–4.0 very large effect, and >4 nearly perfect (Hopkins et al., 2009; Barbosa et al., 2018). The intraclass correlation coefficient (ICC) from a two-way random effects model was computed for single (ICC = 0.04, 95% CI: 0.02–0.06) and average measures (ICC = 0.04, 95% CI: 0.25–0.46) with  $\alpha$  Cronbach's coefficient ( $\alpha = 0.36$ ) (Koo and Li, 2016). Statistical significance was set at  $p < 0.05$  and data are presented as the mean  $\pm$  SD. All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 27.0 (Armonk, NY: IBM Corp) and JASP software (JASP Team, 2019; jasp-stats.org). Data visualization was

produced by Graph Pad Prism (GraphPad Software, CA, USA).

## RESULTS

### Baseline Characteristics, Accumulated Training Load, and Perceived Exertion According to Age Group, Maturity Band, and Relative Age (z Score)

Figure 1 shows the baseline characteristics, accumulated training load, and perceived exertion according to age group, maturity band, and relative age using z scores.

Table 2 presents the OR, frequency, and distribution of birth quartiles relating to age group, maturity band, and overall population. U17 players were 2.35 (95% CI: 1.25–4.51) times more likely to fall into Q1 whereas there was the slightest chance to be in Q2 (95% CI: 2.38–0.60) and Q3 (95% CI: 2.38–0.60). U15 players were 1.60 (95% CI: 0.19–4.33) times more likely to be in Q3. A negative magnitude for OR was found in all quartile comparisons within maturation status (95% CI: 6.72–0.64), except for Mid-PHV on Q2 (95% CI: 0.19–4.33). Only Pre-PHV did not show statistically significant differences ( $p = 0.054$ ).

**TABLE 2** | Odds ratio, frequency, and distribution of birth quartiles relating to age group, maturity band, and overall population.

Variables	Q1 n (%)	Q2 n (%)	Q3 n (%)	Q4 n (%)	Q1 vs. Q4 <sup>a</sup> OR (95%CI)	Q2 vs. Q4* OR (95%CI)	Q3 vs. Q4* OR (95%CI)	p value
<b>Age group</b>								
U15 (n = 102)	10 (13.69)	27 (22.98)	31 (36.69)	34 (36.96)	1.87 (−0.35–4.94)	−0.87 (−2.64–1.31)	1.60 (0.19–4.33)	0.001
U17 (n = 99)	18 (22.31)	11 (15.07)	37 (43.02)	33 (35.87)	2.35 (1.25–4.51)	−1.43 (−2.38–0.60)	0.46 (−0.31–1.23)	0.001
U19 (n = 120)	45 (61.64)	35 (47.95)	18 (20.93)	25 (27.17)	—	—	—	—
<b>Maturation band</b>								
Pre-PHV (n = 52)	5 (9.62)	22 (42.31)	5 (9.62)	20 (38.46)	−3.57 (−6.72–−2.12)	0.62 (−1.60–2.60)	−2.68 (−6.02–−1.12)	0.054
Mid-PHV (n = 65)	24 (36.92)	5 (7.69)	21 (32.31)	15 (23.08)	−1.34 (−2.25–−0.51)	−0.61 (−2.59–1.07)	−0.82 (−3.14–0.64)	0.003
Post-PHV (n = 207)	44 (21.26)	46 (22.22)	60 (28.99)	57 (27.54)	—	—	—	—

\*Reference group; significant differences are verified as: (a) Q1 vs. Q4; (b) Q2 vs. Q4; (c) Q3 vs. Q4. Abbreviations: CI, confidence interval; PHV, peak height velocity; OR, odds ratio; Q—quartile; U—under.

**TABLE 3** | Mean external training load, heart rate-based measures, and perceived exertion for each age group examined.

Variables	Age group			Between-subject			Within-subject			Post-hoc
	U15 (n = 20)	U17 (n = 20)	U19 (n = 20)	F	p	$\eta^2$	F	p	$\eta^2$	
<b>External load</b>										
TD (m)	5,316.18 ± 1,354.45	6,021.45 ± 1,675.64	4,750.43 ± 1,593.46	18.465	0.000	0.103	7.442	0.001	0.047	a,b,c
AvS (m·min <sup>−1</sup> )	49.96 ± 16.35	56.84 ± 34.51	45.83 ± 15.60	6.192	0.002	0.037	4.550	0.011	0.030	a
MRS (m·s <sup>−1</sup> )	6.58 ± 0.82	7.94 ± 3.12	7.43 ± 1.15	13.014	0.000	0.075	5.125	0.013	0.033	a,b
rHSR (m)	53.23 ± 58.34	166.06 ± 458.95	72.41 ± 65.95	5.525	0.004	0.033	4.398	0.007	0.013	a,c
HMLD (m)	489.11 ± 228.44	730.56 ± 483.38	524.90 ± 291.37	14.395	0.000	0.082	5.599	0.124	0.004	a,c
SPR (m)	28.13 ± 41.66	130.42 ± 462.56	40.16 ± 50.43	4.773	0.009	0.029	4.032	0.019	0.026	a,c
SPR_N (n)	1.85 ± 2.46	4.83 ± 4.81	3.12 ± 2.92	18.363	0.000	0.103	4.335	0.014	0.028	a,b,c
DSL (a.u.)	247.21 ± 135.86	261.28 ± 121.73	245.19 ± 144.87	0.439	0.645	0.003	0.512	0.600	0.003	-
ACC (m·s <sup>−2</sup> )	33.62 ± 18.80	53.76 ± 20.62	49.90 ± 20.19	26.636	0.000	0.156	11.43	0.000	0.071	a,b
DEC (m·s <sup>−2</sup> )	30.27 ± 19.77	49.77 ± 25.08	44.01 ± 22.53	20.103	0.000	0.111	7.378	0.001	0.047	a,b
<b>Heart rate</b>										
HRmax	185.69 ± 9.96	188.64 ± 9.09	184.00 ± 10.54	3.057	0.048	0.019	2.103	0.124	0.014	b
AvHR	140.00 ± 9.71	136.53 ± 10.91	132.15 ± 11.52	6.024	0.003	0.036	4.996	0.007	0.032	b,c
%HRmax	75.71 ± 5.26	73.79 ± 5.93	71.65 ± 204.88	14.963	0.000	0.085	6.634	0.002	0.042	b,c
Akubat TRIMP	91.90 ± 34.18	94.03 ± 31.78	81.56 ± 29.13	5.069	0.007	0.082	3.983	0.020	0.026	c
<b>Perceived exertion</b>										
RPE (a.u.)	13.73 ± 1.91	13.51 ± 1.76	12.45 ± 2.50	11.964	0.000	0.069	0.853	0.427	0.006	a,c
sRPE (a.u.)	2056.51 ± 171.87	1835.40 ± 158.71	2497.99 ± 224.69	11.964	0.000	0.069	0.853	0.427	0.006	a,c
TQR (a.u.)	16.38 ± 1.92	16.24 ± 1.81	15.21 ± 2.16	11.923	0.000	0.103	0.062	0.940	0.000	a,c

Significant differences are verified as: (a) U15 vs. U17; (b) U15 vs. U19; (c) U17 vs. U19. Abbreviations: ACC, acceleration; AvHR, average heart rate. AvS—average speed; DEC—deceleration; HMLD, high metabolic load distance; HRmax, maximal heart rate; MRS, maximum running speed; n—number of events; RPE, ratings of perceived exertion; SPR, average sprint distance; SPR\_N - number of sprints; sRPE, session ratings of perceived exertion; TD, total distance; TQR, total quality recovery; TRIMP, training impulse; U—under.

## Effect of Age Group, Group Maturation Status, and Relative Age on Accumulated Training Load and Perceived Exertion

Inferential analysis is displayed in **Table 3** and **Table 4**, reporting between- and within-subject differences for age group and maturity band. Between-subject analysis reported significant differences in all variables on age group comparison ( $F = 0.439$  to  $26.636$ ,  $p = 0.000$  to  $0.019$ ,  $\eta^2 = 0.003$ – $0.037$ ), except in DSL ( $F = 0.439$ ,  $p = 0.645$ ,  $\eta^2 = 0.003$ ). All external training load

measures had a higher magnitude on U17 players, as well HRmax, Akubat TRIMP, and TQR. AvHR, %HRmax, RPE, and sRPE were greater in U15 players. Furthermore, within-subject analysis also showed no significant differences in DSL ( $F = 0.512$ ,  $p = 0.600$ ,  $\eta^2 = 0.003$ ). Also, differences without statistical significance were found for HMLD ( $F = 5.599$ ,  $p = 0.124$ ,  $\eta^2 = 0.004$ ), HRmax ( $F = 2.103$ ,  $p = 0.124$ ,  $\eta^2 = 0.014$ ), and perceived exertion ( $F = 0.103$  to  $0.853$ ,  $p = 0.427$  to  $0.94$ ,  $\eta^2 = 0.000$ – $0.006$ ).

Between-subject analysis on maturity band comparison demonstrated significant differences for external measures,

**TABLE 4** | Mean external training load, heart rate-based measures, and perceived exertion for each age group examined.

Variables	Maturity band			Between-subject			Within-subject			Post-hoc
	Pre-PHV (n = 52)	Mid-PHV (n = 65)	Post-PHV (n = 207)	F	p	$\eta^2$	F	p	$\eta^2$	
<b>External load</b>										
TD (m)	5,302.62 ± 1,444.91	5,323.92 ± 1,559.22	5,318.28 ± 1702.01	0.003	0.997	0.000	7.442	0.001	0.047	-
AvS (m·min <sup>-1</sup> )	49.923 ± 16.35	52.39 ± 25.91	50.04 ± 24.27	0.260	0.771	0.002	4.550	0.011	0.030	-
MRS (m·s <sup>-1</sup> )	6.55 ± 0.93	7.08 ± 1.64	7.59 ± 2.22	6.593	0.002	0.039	5.125	0.013	0.033	b
rHSR (m)	57.65 ± 65.68	65.85 ± 69.67	84.85 ± 82.19	3.400	0.035	0.037	4.398	0.007	0.013	-
HMLD (m)	492.25 ± 244.24	533.99 ± 271.52	582.30 ± 304.15	2.301	0.102	0.014	5.599	0.124	0.004	-
SPR (m)	49.02 ± 17.46	52.39 ± 25.91	50.04 ± 25.91	3.335	0.037	0.020	4.032	0.019	0.026	-
SPR_N (n)	6.55 ± 0.93	7.07 ± 1.64	7.59 ± 2.22	7.268	0.001	0.043	4.335	0.014	0.028	b,c
DSL (a.u.)	253.44 ± 133.61	233.31 ± 135.73	255.54 ± 135.43	0.681	0.507	0.004	0.512	0.600	0.003	b,c
ACC (m·s <sup>-2</sup> )	33.48 ± 18.71	41.29 ± 21.98	50.55 ± 20.66	16.293	0.000	0.092	11.43	0.000	0.071	b,c
DEC (m·s <sup>-2</sup> )	32.04 ± 20.97	34.82 ± 21.51	45.88 ± 24.12	10.773	0.000	0.063	7.378	0.001	0.047	b,c
<b>Heart rate</b>										
HRmax	184.63 ± 10.64	186.69 ± 8.34	186.05 ± 10.46	6.024	0.003	0.036	0.191	0.826	0.001	b,c
AvHR	139.17 ± 10.61	138.48 ± 9.45	134.36 ± 11.65	14.963	0.000	0.085	0.642	0.527	0.004	-
%HRmax	75.40 ± 5.70	74.29 ± 5.44	72.81 ± 6.30	14.424	0.000	0.082	0.969	0.381	0.006	b,c
Akubat TRIMP	88.67 ± 36.80	92.37 ± 27.69	87.44 ± 32.03	1.105	0.333	0.007	1.277	0.280	0.008	b,c
<b>Perceived exertion</b>										
RPE (a.u.)	13.65 ± 1.83	13.49 ± 2.07	12.95 ± 2.28	3.057	0.048	0.019	0.211	0.810	0.001	b,c
sRPE (a.u.)	1,228.85 ± 164.21	1,214.31 ± 186.30	1,165.65 ± 204.88	3.057	0.048	0.019	0.211	0.810	0.001	b,c
TQR (a.u.)	16.50 ± 1.79	15.71 ± 2.23	15.80 ± 2.03	2.789	0.063	0.017	0.300	0.741	0.002	-

Significant differences are verified as: (a) U15 vs. U17; (b) U15 vs. U19; (c) U17 vs. U19. Abbreviations: ACC, acceleration; AvHR, average heart rate. AvS—average speed; DEC—deceleration; HMLD, high metabolic load distance; HRmax, maximal heart rate; MRS, maximum running speed; n—number of events; RPE, ratings of perceived exertion; SPR, average sprint distance; SPR\_N - number of sprints; sRPE, session ratings of perceived exertion; TD, total distance; TQR, total quality recovery; TRIMP, training impulse; U—under.

specifically MRS ( $F = 6.593$ ,  $p = 0.002$ ,  $\eta^2 = 0.039$ ), rHSR ( $F = 3.400$ ,  $p = 0.035$ ,  $\eta^2 = 0.037$ ), SPR ( $F = 3.335$ ,  $p = 0.037$ ,  $\eta^2 = 0.020$ ), SPR\_N ( $F = 7.268$ ,  $p = 0.001$ ,  $\eta^2 = 0.043$ ), ACC ( $F = 16.293$ ,  $p = 0.000$ ,  $\eta^2 = 0.092$ ), and DEC ( $F = 10.773$ ,  $p = 0.000$ ,  $\eta^2 = 0.063$ ). Post-PHV players covered all of these variables with statistical significance, except SPR which showed higher values in the Pre-PHV players. Heart rate measures exhibited significant differences for HRmax ( $F = 6.024$ ,  $p = 0.002$ ,  $\eta^2 = 0.039$ ), AvHR ( $F = 14.963$ ,  $p = 0.000$ ,  $\eta^2 = 0.085$ ), and %HRmax ( $F = 14.424$ ,  $p = 0.000$ ,  $\eta^2 = 0.082$ ). Pre-PHV players had higher AvHR and %HR<sub>max</sub> compared to the Mid-PHV band. Perceived exertion was higher in Pre-PHV players, without differences, though.

The pairwise comparison was analyzed according to age groups (i.e., U15 vs. U17, U17 vs. U19, and U15 vs. U19) and maturity band (i.e., Pre-vs. Mid-PHV, Mid-vs. Post-PHV, and Pre-vs. Post-PHV), reporting the following ES for each variable (negative to large effects): TD ( $d = -0.461$ – $0.779$ ), AvS ( $d = -0.05$ – $0.427$ ), MRS ( $d = -0.602$ – $0.225$ ), rHSR ( $d = -0.662$ – $0.483$ ), HMLD ( $d = -0.600$  to  $-0.249$ ), SPR ( $d =$ ), SPR\_N ( $d = -0.516$ – $0.119$ ), DSL ( $d = -0.164$ – $0.441$ ), ACC ( $d = -1.022$ – $0.189$ ), DEC ( $d = -1.022$ – $0.189$ ), HRmax ( $d = -0.308$ – $0.467$ ), AvHR ( $d = 0.070$ – $0.731$ ), %HRmax ( $d = 0.2$ – $0.719$ ), Akubat TRIMP ( $d = -1.86$ – $0.087$ ), RPE ( $d = 0.082$ – $0.568$ ), sRPE ( $d = 0.082$ – $0.568$ ), and TQR ( $d = -0.045$ – $0.571$ ). Previous standardized (Cohen) differences are presented in **Figure 2** according to age group and

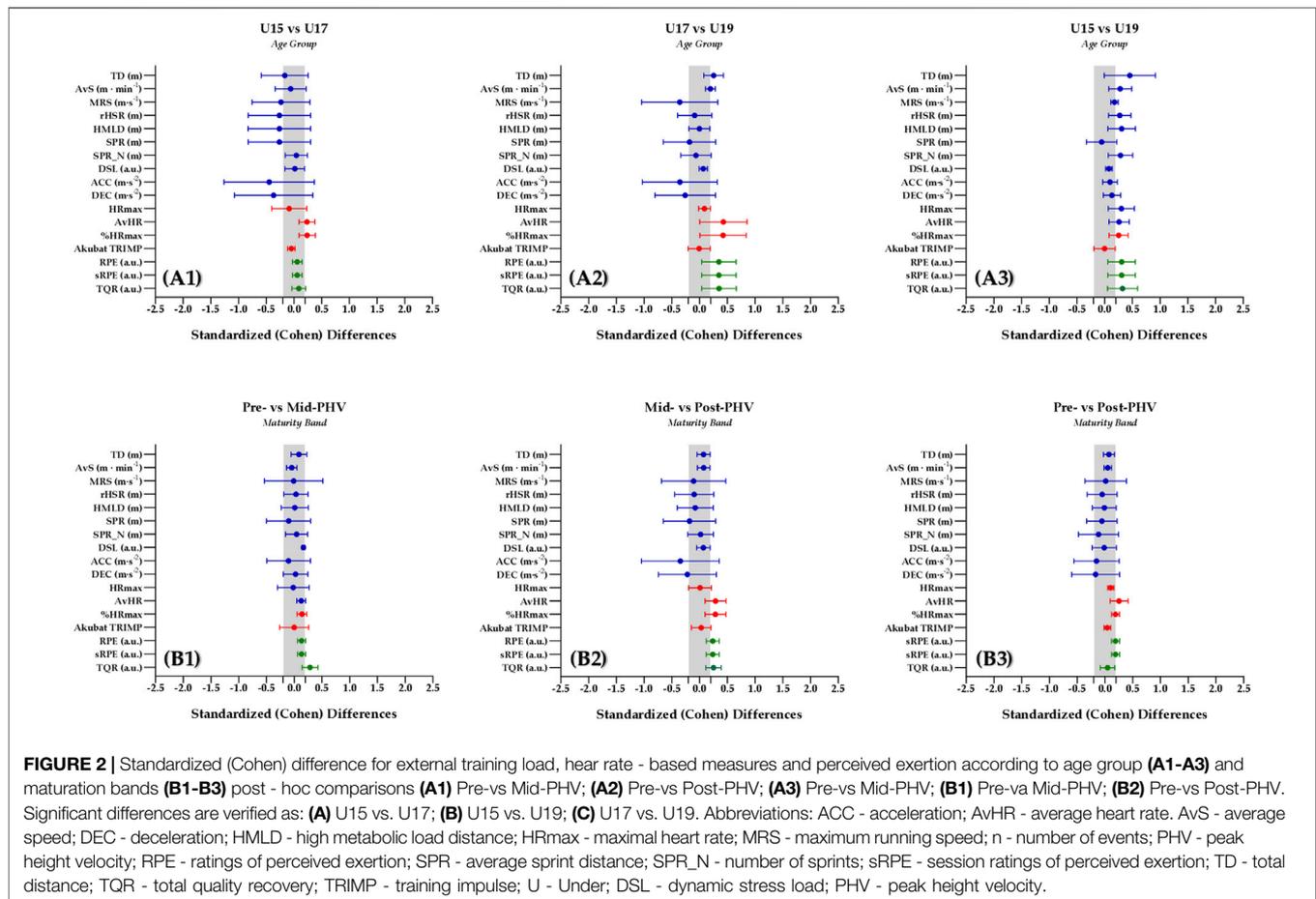
maturity bands for external training load, hear rate-based measures, and perceived exertion.

## Interaction Effects Amongst Age Group, Maturation Status, and Relative Age on Accumulated Training Load and Perceived Exertion

Interaction effects were found for age group x maturity band x relative age ( $\Lambda$  Pillai's = 0.391,  $\Lambda$  Wilk's = 0.609,  $F = 11.385$ ,  $p = 0.000$ ,  $\eta^2 = 0.391$ ) and maturity band x relative age ( $\Lambda$  Pillai's = 0.252,  $\Lambda$  Wilk's = 0.769,  $F = 0.955$ ,  $p = 0.004$ ,  $\eta^2 = 0.112$ ). No isolated interaction was found for age group x maturity band ( $\Lambda$  Pillai's = 0.122,  $\Lambda$  Wilk's = 0.881,  $F = 1.159$ ,  $p = 0.066$ ,  $\eta^2 = 0.083$ ) and age group x relative age ( $\Lambda$  Pillai's = 0.327,  $\Lambda$  Wilk's = 0.710,  $F = 1.261$ ,  $p = 0.064$ ,  $\eta^2 = 0.065$ ).

## DISCUSSION

The aims of this study were to analyze the influence of chronological age, relative age, and biological maturation on accumulated training load and perceived exertion in young sub-elite football players. Also, we intended to understand the interaction effects amongst age grouping, maturation status, and birth quartiles on accumulated training load and perceived exertion in this target population.



## Effect of Age Group, Group Maturation Status, and Relative Age on Accumulated Training Load and Perceived Exertion

Current research has confirmed an RAE on accumulated training load and perceived exertion when using an annual age-grouping strategy. U17 players and U15 players were 2.35 (95% CI: 1.25–4.51) and 1.60 (95% CI: 0.19–4.33) times more likely to pertain to Q1 and Q3. The obtained results were congruent with the hypothesis raised, being able to assume that the relative age and biological maturation would have an influence on the accumulated training load and perceived exertion in young football players. Previous research has reported a selection bias with an age-related increase with a maturity dependence over U12 age groups (Hill et al., 2020). Indeed, RAE increased linearly with relative age differences depending on category, skill level, and sport context (Cobley et al., 2009). However, previous studies have pointed out that baseline characteristics did not differ by birth quartile except for age and PHV (Figueiredo et al., 2019). Inconsistencies have been reported when seeking to understand the RAE in physical demands (Hill et al., 2020; Patel et al., 2020; Figueiredo et al., 2021). Patel et al. (2020) reported that somatic maturity and anthropometric and physical performance characteristics distinguished retained or dropout individuals in

an age group-dependent manner as opposed to birth quartile. The present study found a negative magnitude for all quartile comparisons within maturation status (95% CI: 6.72–0.64), except for Mid-PHV on Q2 (95% CI: 0.19–4.33). In line with these assumptions, the literature recommends strategies to reduce selection biases and better identify, retain, and develop football players (Hill et al., 2020). Applying a bio-banding process could also bring potential benefits for strength and conditioning of youth athletes (Malina et al., 2015, 2019; Cumming et al., 2017). For these reasons, the present study also sought to establish the differences between age groups and biological band cut-offs on accumulated training load and perceived exertion.

Between- and within-subject analysis reported significant differences in all variables on age group comparison, except in DSL. Also, within-subject analysis also showed no significant differences for HMLD, HRmax, and perceived exertion. Several studies have demonstrated an age-related influence on physical performance characteristics in young elite football players (Rubajczyk and Rokita, 2018; Patel et al., 2019; Edwards et al., 2021). However, both match running and training load seem to be more influenced by biological maturation and anthropometry than by individual chronological age (Nobari et al., 2021a; Salter et al., 2021). The results of the present research seem to corroborate this evidence since the between-subject analysis on

maturity band comparison demonstrated significant differences for external measures. Post-PHV players presented high demands in all external training loads, except pre-PHV players. In contrast, Nobari et al. (2021a) achieved no significant differences in accumulated training load and maturation status in U16 players. The authors controlled seasonal phases unlike the current study. It is therefore difficult to generalize RPE outcomes, due to the wide variation according to different training settings, players, and coaches' strategies (Lupo et al., 2019b). Thus, futures research should also include the influence of seasonal variation on the accumulated training load as has been reported previously for sub-elite youth football (Teixeira et al., 2021a; 2021b). Indeed, weekly accumulated training load varied according to age group, training day, inter-week, and playing position (Teixeira et al., 2021b). An intra-individual variation was also reported in youth-perceived exertion in different intensity training sessions (Lupo et al., 2017). The current research demonstrated differences in the internal training load and perceived exertion amongst maturation bands. Pre-PHV players had a higher AvHR and %HRmax compared to the Mid-PHV band. Perceived exertion was higher in Pre-PHV players, without differences, though. Previous research has established that perceived exertion seems to be better explained by variables associated with trainability, maturation, and stage of development than by training conditions or demands (Malina et al., 2019). Perceived exertion in young football players may also be influenced by psycho-physiological determinants, such as self-perception of competence and practice experience (Ferraz et al., 2018a, 2020; Branquinho et al., 2021). Also, the influence of wellness status must also be considered on accumulated training load and perceived exertion (Clemente et al., 2017, 2020).

### **Interaction Effects Amongst Age Group, Maturation Status, and Relative Age on Accumulated Training Load and Perceived Exertion**

Multivariate interaction effects amongst conditioned factor and accumulated training load have been previously reported in elite and sub-elite football environments (Teixeira et al., 2021b; Maughan et al., 2021). Current findings displayed an interaction effect between age group x maturity band x relative age and maturity band x relative age. This study adds new practical insights as previous research had not considered maturational variables in training load variability (Maughan et al., 2021; Teixeira et al., 2021a, 2021b). Maughan et al. (2021) described the main effects amongst playing position and stage of season for training and match load. Teixeira et al. (2021b) observed interaction effect for TD between inter-day, inter-week, and age, as well as amongst the inter-day, inter-week, age group, and playing position for DEC. Otherwise, the playing position effect on physical demands seems to be distinguished in elite and sub-elite contexts (Teixeira et al., 2021b; Maughan et al., 2021).

The literature reported a minimum effect on the weekly training in sub-elite youth football training (Teixeira et al., 2021b). Negative to large effects were reported in the current research, however the magnitude of effects should be interpreted differently depending on the targeting group as well as the training setting (Flanagan, 2013). Albeit, seasonal loading variation seems to be influenced by seasonal factors as well as others conditioned and independent factors (i.e., weekly microcycle, player's starting status, training mode, and contextual variables) (Teixeira et al., 2021a). Within-athlete variability should also be considered to evaluate training load and perceived exertion across the competitive season (Malcata and Hopkins, 2014; Younesi et al., 2021). The classic concept of training cycles (Issurin, 2010) tends not to exist in the coaching context of team sports such as football, particularly during competitive periods (Brito et al., 2016; Clemente et al., 2020; Nobari et al., 2021a). Here, there is a regular methodological pattern (i.e., weekly pattern) as presented in elite young players (Wrigley et al., 2012; Abade et al., 2014; Coutinho et al., 2015). Recently, a systematic review clarified a high load variation in a weekly microcycle and a limited variation across a competitive season in elite and sub-elite football (Teixeira et al., 2021a; 2021b). The current research adds evidence for an interactive influence of chronological age, relative age, and maturation in weekly training load patterns at sub-elite football environments. Coaches should be advised to design and prescribe internal and external training intensity, adjusting stimulus into growth and maturity status of the youth football players.

### **Limitations and Future Perspectives**

The current study has some limitations, which affect how the results should be interpreted: 1) match data were not included in the present data analysis, and periodization structure considers the whole training session. Indeed, match running performance should also be included as well as the contextual factor influence (Gonçalves et al., 2019; Teixeira et al., 2021c); 2) technical factors (i.e., running with or without the ball) (Yi et al., 2020a; 2020b), tactical key indicators (i.e., possession strategies) (Bradley et al., 2014), and collective behavior must be considered for a more integrative and ecological analysis (Bradley and Ade, 2018; Carling, 2013; Ferraz, et al., 2018b; Folgado et al., 2018; Gonçalves et al., 2018); 3) the methodological bias evidenced for the different formulas to estimate maturity state should be considered when interpreting current findings (Malina et al., 2015; Cumming, 2018); 4) cumulative effects of pre-match training were not controlled in this research (Branquinho et al., 2021; Trecroci, et al., 2020a, 2020b); and 5) current training data reflect only one sub-elite football academy and hence cannot be extended to other contexts. Hence, more analyses are required for this purpose, with a wider follow-up. Future research should also consider the relationship of accumulated training load, such as congested fixture, players' starting status, and competitive level (Teixeira et al., 2021a; 2021b). It would be likewise pertinent to study female football players to develop the

generalizability of the achieved results (Nobari et al., 2021c). The comparison between bio-banding and age-grouping should also be analyzed using a quasi-experimental methodology and not just an observational prospective (Arede et al., 2021). Individualized reference values for internal and external training intensity in sub-elite training insights is another key point to explore (Boullousa et al., 2020; Rago et al., 2020; Oliveira et al., 2021). Also, resultant composition equations should be developed to extract meaning in the emergence of new source information (Rojas-Valverde et al., 2019, 2020).

## CONCLUSION

The current research has confirmed an interaction effect amongst chronological age, relative age, and maturation on accumulated training load, however perceived exertion does not seem to differ either in age group and maturity status. Also, the within-between interaction showed significant differences in all variables on age group and maturation status comparison. This study provides new useful insights to prescribe and control training load in young sub-elite football players.

## DATA AVAILABILITY STATEMENT

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

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## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The experimental approach was approved and followed by the local Ethical Committee from University of Trás-os-Montes e Alto Douro (3379-5002PA67807). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

JT, AA, PF and RF conceptualized the study. ML, JR, and TB contributed to the methodology. JT, PF and RF analyzed the data. JT and AA drafted the manuscript. AS, AM and RF revised the manuscript. All authors contributed to the article and approved the submitted version.

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