Journal of Human Kinetics volume 65/2018, 235-248 DOI: 10.2478/hukin-2018-0032

Section III – Sports Training

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Training Loads and RSA and Aerobic Performance Changes During the Preseason in Youth Soccer Squads

by
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The aims of this study were to compare the internal training load (ITL) in soccer players of two competitive age groups (under-15 [U-15] and under-19 [U-19]) during an 8-week preseason training period and compare the associated changes in physical performance measures. Eighteen U-15 and twelve U-19 players were monitored over an 8-week period during the preseason phase. The ITL was monitored using the session rating of perceived exertion (RPE) method. Before and after the preseason period, physical performance was assessed by best (RSA_{best}) and mean (RSA_{mean}) times in a repeated sprint ability (RSA) test and peak velocity derived from the Carminatti test (PVT-CAR). Total weekly ITL increased with age (U-15: 13770 ± 874 AU vs. U-19: 33584 ± 2506 AU; $p < 0.001$). In addition, U-19 players perceived training sessions as heavier than U-15 players (6.1 ± 0.3 vs. 5.3 ± 0.3 AU, respectively; $p < 0.001$). After the preseason period, very likely to almost certainly positive changes were observed for all performance measures in both age groups. However, the U-15 group had possibly superior gains in RSA_{best} (+1.40%, 90%CL -0.29 to 3.05, with ES = 0.35) and likely higher effects in RSA_{mean} (+1.89%, 90%CL 0.04 to 3.70, with ES = 0.53) and $PV_{T\text{-}CAR}$ (+2.71%, 90%CL 0.35 to 5.01, with ES = 0.37) compared to the U-19 group. In conclusion, our findings demonstrate that the U-19 group accumulate higher total weekly ITLs than the U-15 group during the preseason phase due to longer and heavier training sessions. However, the U-15 group obtained superior gains in soccer-specific physical abilities while accumulating half the total ITLs during lighter training sessions.

Key words: *field testing; physical adaptation; rating of perceived exertion; team sports; youth athletes.*

Introduction

Long-term athlete development (LTAD) programs underline that preparation of youths to become successful adult elite athletes is a multi-factorial process (Vaeyens et al., 2008). Briefly, the current LTAD model available offers an integrative approach to optimize the athletic development of youths throughout the childhood and adolescence (i.e., identifying when and why

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Authors submitted their contribution to the article to the editorial board.
Accepted for printing in the Journal of Human Kinetics vol. 65/2018 in December 2018.

training of each motor ability should be emphasized), taking into account the interaction between growth, maturation and training practices (Lloyd and Oliver, 2012). During childhood and adolescence, coaches and strength and conditioning professionals focus on developing all physical abilities and sports-specific technical-tactical skills, aiming to progressively prepare their players to cope with high demands of competition in adulthood (Ford et al., 2011). To achieve this goal, and respecting the maturational status of the athletes (Lloyd et al., 2014), a gradual and systematic progression of overall training loads placed on youth players is expected. In theory, this planned progression will allow them to attain optimal development of their physical abilities, avoiding negative consequences of excessive training and insufficient recovery (e.g., injury, illness, and overtraining) (Gabbett et al., 2014; Wrigley et al., 2012). Careful examination of the current literature reveals that this optimal loading is not always observed in young team sports athletes (Noon et al., 2015; Oliver et al., 2015; Czuba et al., 2014).

Several studies have been designed to describe and quantify the training loads experienced during the preseason and in-season phases in junior (late adolescence) and senior players (Coutinho et al., 2015; Malone et al., 2015; Miloski et al., 2015; Rabelo et al., 2016). However, in the context of talent identification and development, it is widely advocated that the two main composite factors of the overall training load (i.e., volume and intensity), should be structured according to the biological development of the athlete (Ford et al., 2011; Gabbett et al., 2014). Although appealing, few studies have extensively addressed the training load profile in young players, with a special focus on comparing age groups over a longer period (> 4-6 weeks) during the team sports preseason (Gabbett et al., 2014). Objective data using GPS technology have suggested the existence of age- and maturity-related variations in running match performance (e.g., total distance covered) (Buchheit et al., 2010c; Buchheit and Mendez-Villanueva 2014) and time-motion during technical-tactical training sessions (Abade et al., 2014; Gastin et al., 2013). In general, these studies support the notion that match and training demands (external load indicators) increase as players become older.

On the other hand, there are other studies showing that matches and training intensities, evaluated by internal load measures such as the rating of perceived exertion (RPE) or heart rate (HR), do not change across competitive age categories (e.g., U-14, U-16 and U-18) (Mendez-Villanueva et al., 2013; Wrigley et al., 2012). Of interest, several of these previous studies have been performed during the in-season phase, a period characterized by reduced training loads (volume and intensity) compared to the preseason phase (Malone et al., 2015; Miloski et al., 2015). In this sense, further studies during the preseason phase are required to provide additional information on training volume and intensity placed on adolescent players involved in systematic and standardized training programs.

The development of aerobic performance (i.e., intermittent endurance running capacity) and repeated sprint ability (RSA) during the specialization years in soccer is considered fundamental to compete at professional level (Roescher et al., 2010; Valente-dos-Santos et al., 2012). Intermittent endurance running and RSA are positively associated with the ability to perform intermittent high-intensity efforts during soccer matches (Da Silva et al., 2016; Rampinini et al., 2007). Furthermore, both have been successful in discriminating players of different competitive levels (Impellizzeri et al., 2008; Vaeyens et al., 2006). These data highlight the importance of well-designed preseason training to enhance intermittent endurance running and RSA performance. Some studies have reported positive gains in RSA and intermittent endurance running performance after controlled experimental interventions using different types of training (Buchheit et al., 2008, 2010a; Da Silva et al., 2015). However, further studies describing training loads and their subsequent effects on soccer match-related physical fitness attributes (i.e., intermittent endurance and RSA performances) in youth players after a regular and systematic training process without any external manipulation during the preseason phase are warranted. For technical staff dealing with adolescent players of different ages, it is also of practical interest and relevant to know whether the magnitude of adaptations in performance could be affected by age (Philippaerts et al., 2006). In practical terms, the resulting findings of this study can provide coaches and technical staffs with a better understanding of the player's adaptive capacity within each age group to enhance both intermittent endurance and RSA performance. In addition, this study may give some support in identifying a period of optimal trainability of intermittent endurance running capacity and RSA based on chronological age.

Thus, the aims of the present study were: (1) to compare internal training loads (as measured by the RPE) in soccer players of two competitive age groups (under-15 [U-15] and under-19 [U-19]) regularly training in a Brazilian professional soccer academy during the preseason phase (8-weeks), and (2) to compare the associated changes in physical performance outcomes (i.e., RSA and T-CAR) of these youth soccer players. Our hypothesis was that U-19 players would have greater internal training loads than U-15 throughout the preseason phase. As a consequence of these higher training loads placed on older players, U-19 players would exhibit a superior gain in physical performance compared to U-15 players.

Methods

Participants

Thirty youth male soccer players were recruited from a professional soccer team competing in the first division of the Brazilian National Championship. The players belonged to one of the following competitive age categories: Under-15 (n = 18; age: 14.7 ± 0.5 years, body mass: 59.1 ± 7.0 kg, body height: 169.1 ± 7.8 cm, years of systematic practice in soccer: 5.4 ± 2.3 years) and Under-19 (n = 12; age: 18.9 ± 0.9 years, body mass: 67.8 ± 7.5 kg, body height: 175.1 ± 7.4 cm, years of experience: 8.6 ± 1.8 years). Only outfield players were included in this study. The distribution of the players by a playing position in each competitive age category was as follows: under-15 (3 central defenders, 4 full-backs, 6 midfielders, and 5 attackers) and under-19 (3 central defenders, 2 full-backs, 5 midfielders, and 2 attackers). The inclusion criteria for the study were regular participation in more than 90% of training sessions during the period of investigation, not suffering from injuries during the same period, and not taking any medication that could alter the outcomes of this study. The study was approved by the local research Ethics Committee, with participants and their legal guardians (in < 18 years players) providing written informed assent and consent, respectively, before participation in the study (protocol 1.197.858). The > 18 years players signed the informed consent form themselves. Participation was voluntary and players could withdraw at any time of the study.

Design and Procedures

The soccer players were assessed before (pre-training) and after (post-training) an 8-week preseason training period (Table 1). The study period comprised physical training (PT) sessions (interval training, strength, plyometric training, speed), technical (TEC) and tactical (TAC) training, and friendly matches (FM) for both competitive categories. Physical training was defined as a programmed session that was devoted to enabling players to cope with the physical demands of match-play. Sessions focused on player's tactical understanding and/or their technical ability, were defined as TEC/TAC. When the session included both physical and technical activities, it was defined as PT/TEC. Prior to the respective preseason, players had an off-season period of ~1-2 months. The players completed the following evaluation timetable: 1) medical screening [Week 1: morning], 2) anthropometric assessments [Week 1: Monday and Tuesday - afternoon], 3) a repeated-sprint test (6 x 40 m) in order to assess both repeated-sprint and change in direction abilities [Weeks 2 and 11: Tuesday - afternoon], and 4) Carminatti's Test (T-CAR) aiming to evaluate the intermittent endurance running capacity [Weeks 2 and 11: Thursday - afternoon]. The RSA and T-CAR performances were measured the week immediately before and after the beginning and end of the preseason period, respectively. The assessments were performed on a grass field at the training facilities of the professional club. Players were habituated with test procedures as per their usual medical and fitness assessments. A period of 48 hours without training or strenuous exercise was undertaken prior to the physical assessment days to minimize any residual fatigue. During the study period, the internal training load (ITL) of each participant was monitored by means of the session rating of perceived exertion (RPE) method (Foster et al., 2001). The session-RPE method was used as proposed by Foster et al. (2001) to quantify the ITL. Thirty minutes after the session, players were asked "How intense was your session?". They were requested to make sure that their RPE referred to the intensity of the whole session. The players were required to give the answer without any contact with each other, to avoid the influence of peer responses. The reported RPE score was then multiplied by the total session duration, in minutes, to indicate the ITL. All players were previously familiarized with the use of the RPE scale.

Repeated Sprint Ability (RSA)

Before the RSA test, players performed a standardized 10 min warm-up of progressive runs and accelerations that were administered by each age category's physical coach. The RSA test consisted of 6 × 40 m (20 + 20 m with a 180 ° change of direction) sprints separated by 20 s of passive recovery (Impellizzeri et al., 2008; Rampinini et al., 2007). The players started 0.5 m behind the start line which was marked by a photocell (Speed Test 6.0 CEFISE®, Nova Odessa, SP, Brazil). Before starting, the players were instructed to run as fast as possible to the end of the 20 m course, which was marked with 2 cones, then perform a quick change in direction (180°) and run in the direction of the start line. Following each sprint, players decelerated and walked to the starting line in readiness for the subsequent sprint. Five seconds prior to the next sprint, the players assumed the starting position and a 3 s regressive countdown was provided to commence their sprint. The best (RSA_{best}) and mean sprint times (RSA_{mean}) were recorded as the performance criteria. The coefficients of variation for RSA_{mean} and RSA_{best} have been reported to be 0.8% and 1.3%, respectively, in professional soccer players (Impellizzeri et al., 2008).

Carminatti's Test (T-CAR)

The test consists of intermittent shuttle runs of 12 s until volitional exhaustion, performed between 2 lines set at progressive distances, with a 6 s recovery between each run and a total stage time of 90 s (Da Silva et al., 2011; Teixeira et al., 2014). The test has a starting velocity of 9 km·h^{-1} over a running distance of 30 m (15 m out and back). The length in a single direction is increased progressively by 1 m at every level. Each stage consists of 5 repetitions with a 6 s walking period between 2 lines set 2.5 m from the starting line (Da Silva et al., 2011; Teixeira et al., 2014). A total of 8–10 players were evaluated simultaneously with the running pace dictated by a pre-recorded audio system (Da Silva et al., 2011; Teixeira et al., 2014). The test ended when participants failed to follow the audio cues on the front line for 2 successive repetitions (using objective criteria applied by observers). The $PV_{T\text{-}CAR}$ was calculated from the distance of the final set completed by the player divided by the time to complete the full set of repetitions. In the event of an incomplete set, peak velocity was interpolated using the equation: PV = v+ (ns/10)*0.6, where "v" was the velocity of the final fully completed stage and "ns" was the number of repetitions completed in the partially completed stage. The peak velocity ($PV_{T\text{-}CAR}$) reached at the end of the test by the athletes was reported as the performance criterion for the T-CAR. Reproducibility of the $PV_{T\text{-}CAR}$ has been reported previously, with replicate tests within a period of 1 week among 34 youth players aged 10.2–13.0 years. The ICC and measurement error expressed as a coefficient of variation for $PV_{T\text{-}CAR}$ were, respectively, 0.89 and 2.30% (0.3 km·h^{-1}) (Teixeira et al., 2014).

Statistical Analysis

The normality of data and homogeneity of variance assumptions were tested using the Shapiro-Wilk and Levene's test, respectively. When assumptions were violated, log-transformations were performed. In order to examine the main training-induced changes in performance measures and differences in the weekly ITL, a two-way repeated measures ANOVA with one between factor (age group: U-15 vs. U-19) and one within factor (time: pre-training vs. post-training or over 8-weeks) was used for each dependent variable. When a significant F value was identified, a Bonferroni post hoc test was performed to identify pairwise differences. Student's unpaired *t* tests were used to compare the total training load and average RPE scores (accumulated over 8-weeks) between age-category groups. Differences between the first and last four weeks for the average total weekly training load and RPE scores within each age group were tested using Student's paired *t* tests. The level of statistical significance was set at $p < 0.05$. These analyses were carried out using SPSS (SPSS 17.0 version, Chicago, Illinois, USA). In addition to the null-hypothesis test, to allow for better interpretation of the results, magnitude-based-inference analyses were used to examine the differences between pre-training and post-training in RSA performance and $PV_{T\text{-}CAR}$. For within- and between-age group comparisons, the chances that the training-induced changes in RSA_{best}, RSA_{mean}, and $PV_{T\text{-}CAR}$ were beneficial/higher (i.e., greater than the smallest worthwhile change, SWC [0.2 multiplied by the between-subject standard deviation]), unclear, or harmful/lower were calculated. Quantitative chances of beneficial/higher or harmful/lower effects were assessed qualitatively as follows: 25 to 75%, possibly; 75 to 95%, likely; 95 to 99%, very likely; and >99%, almost certainly. If the chances of having higher/beneficial or lower/harmful performances were both >5%, the true difference was assessed as unclear/similar (Batterham and Hopkins, 2006). In addition, the standardized mean difference or effect size (ES) of changes (Δ) in RSA_{best}, RSA_{mean}, and $PV_{T\text{-}CAR}$ between the competitive age groups was calculated using the pooled pre-training standard deviation. The criteria to interpret the magnitude of the ES were: ≤ 0.2 trivial, > 0.2-0.6 small, > 0.6-1.2 moderate, > 1.2-2.0 large, and >2.0-4.0 very large (Hopkins et al., 2009). All inference-based analyses were conducted using a publicly available spreadsheet (http:// www.sportsci.org/resource/stats/).

Results

Training Load Profile

The total weekly training load and average RPE scores during the study period are shown in Figure 1. A significant "age group vs. week" interaction was observed for the total weekly training load (Figure 1a, F = 16.608; $p < 0.0001$) and average RPE score (Figure 1b, F = 11.055; $p < 0.001$) throughout the 8 weeks of the preseason. Under 19 players presented a greater total training load (Figure 1e) and perceived the training sessions as heavier (Figure 1f) than U-15 players. The training load was lower in week 1 ($p < 0.05$) in the two competitive age groups. The highest total training load for both the U-15 and U-19 age groups was identified in week 2 (Figure 1a). The average total weekly training load and RPE scores from weeks 1-4 to weeks 5-8 were significantly reduced in the U-15, while remaining unchanged for the U-19 age group (Figures 1c and 1d, respectively).

Changes in physical performance variables after the preseason

Raw values for all performance variables are presented in Table 2. There was a significant main age group effect for $PV_{T\text{-}CAR}$ (F = 30.300; $p < 0.001$), RSA_{best} (F = 30.423; $p < 0.001$), and RSA_{mean} (F = 42.338; $p < 0.001$). Compared with the younger group, U-19 players were *almost certainly* (100/0/0) better in $PV_{T\text{-}CAR}$ (ES: 1.96 and 1.90), RSA_{best} (ES: 1.78 and 1.48), and RSA_{mean} (ES: 2.87 and 1.73) in both pre-training and post-training moments. After the preseason, all performances ($PV_{T\text{-}CAR}$, RSA_{best}, and RSA_{mean}) were significantly improved in both groups (all $p < 0.001$ for the main time effect). There was no ''age group vs. time'' interaction for $PV_{T\text{-}CAR}$ (F = 1.87; $p = 0.18$) or RSA_{best} (F = 1.58; $p = 0.22$). A trend toward a significant ''age group vs. time'' interaction was noted for RSA_{mean} (F = 3.38; $p = 0.08$).

Magnitude-based analyses: within-age groups comparisons

Body mass remained unchanged throughout the preseason period with changes being *likely* trivial in both the U-15 (59.1 ± 7.0 vs. 59.9 ± 6.5 kg, 6/94/0) and U-19 group (67.8 ± 7.5 vs. 68.9 ± 7.0 kg, 21/79/0).

Relative changes and qualitative outcomes resulting from the within-group analysis are also reported in Table 2. After the preseason, RSA_{best}, RSA_{mean}, and $PV_{T\text{-}CAR}$ *almost certainly* improved (100/0/0), increasing by 4.2%, 5.0% and 8.0% in U-15 soccer players, respectively. Large to very large ES for changes was observed. In U-19 soccer players, improvements in RSA_{best} and RSA_{mean} were *very likely* beneficial (99/1/0), whereas for the $PV_{T\text{-}CAR}$ it was *almost certainly* beneficial (100/0/0). After the training period, RSA_{best}, RSA_{mean}, and $PV_{T\text{-}CAR}$ improved by 2.7%, 3.2% and 5.0% in the older age group, respectively. Moderate ES was noticed in RSA_{best}, RSA_{mean}, and $PV_{T\text{-}CAR}$ between the beginning and end of the preseason.

Magnitude-based analyses: between-age groups comparisons for the changes in physical performance

While the "traditional" statistical analyses revealed no differences between age groups for the changes in physical performance variables, analyses of practical significance showed some meaningful differences (Table 3). After the preseason period, changes in RSA_{best} were *possibly* lower in U-19 than in U-15 players (small ES); while improvements in RSA_{mean} (1/12/87) and PV_{T-CAR} (0/18/82) were *likely* lower in U-19 soccer players (small ES).

Relationships between the total training load and changes in physical performance

Relationships between the total training load and changes in RSA_{best}, RSA_{mean}, and PV_{T-CAR} were not significant either in U-15 (r = -0.19, *p* = 0.45; r = 0.02, *p* = 0.95; r = -0.05, *p* = 0.86) or U-19 players (r = -0.26, *p* = 0.42; r = -0.27, *p* = 0.39; r = 0.52, *p* = 0.09). When data from both groups were pooled, a significant and negative moderate correlation was found between the total training load and changes in RSA_{mean} (r = -0.36, *p* = 0.05).

Table 1

Schematic representation of the weekly training schedule during 8 weeks of the preseason phase in U-15 and U-19 soccer players.

Groups	Day	Period	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week
U-15	Monday	M	rest	rest	rest	rest	rest	rest	rest	rest
		A	PT/TEC	PT/TEC	TEC/TAC	PT/TEC	PT/TEC	PT/TEC	PT/TEC	PT/TEC
	Tuesday	M	rest	rest	rest	rest	rest	rest	rest	rest
		A	PT/TEC	PT/TEC	TEC	TEC	PT/TEC	TEC/TAC	TEC	TEC
	Wednesday	M	rest	rest	rest	rest	rest	rest	rest	rest
		A	PT/TEC	TEC	TEC	TEC	TEC/TAC	TEC/TAC	TEC	TEC/TAC
	Thursday	M	rest	rest	rest	rest	rest	rest	rest	rest
		A	PT/TEC	TEC/TAC	PT/TEC	TEC	TEC/TAC	TEC/TAC	TEC/TAC	TAC
	Friday	M	rest	rest	rest	rest	rest	rest	rest	rest
		A	TEC	TEC	rest	TEC/TAC	TAC	FM	TAC	TEC/TAC
	Saturday	M	rest	PT/TEC	rest	TEC/TAC	FM	rest	FM	rest
		A	rest	rest	rest	rest	rest	rest	rest	rest
U-19	Monday	M	PT/TEC	PT/TEC	rest	rest	PT/TEC	rest	rest	rest
		A	rest	PT/TEC	TEC/TAC	rest	rest	rest	rest	rest
	Tuesday	M	PT	PT/TEC	PT/TEC	PT/TEC	TEC/TAC	PT/TEC	PT/TEC	PT/TEC
		A	PT/TEC	rest	rest	rest	rest	rest	rest	rest
	Wednesday	M	PT/TEC	PT/TEC	PT/TEC	PT/TEC	rest	PT/TEC	PT/TEC	PT/TEC
		A	rest	rest	PT/TEC	PT/TEC	FM	rest	rest	rest
	Thursday	M	PT/TEC	TEC/TAC	PT/TEC	PT/TEC	PT/TEC	PT/TEC	PT/TEC	PT/TEC
		A	rest	rest	rest	rest	rest	rest	rest	rest
	Friday	M	rest	TEC/TAC	TEC/TAC	PT/TEC	TEC/TAC	TEC/TAC	TEC/TAC	TEC/TAC
		A	PT/TEC	rest	rest	rest	rest	rest	rest	rest
	Saturday	M	rest	TEC/TAC	TEC/TAC	PT/TEC	TAC	TAC	TAC	TAC
		A	rest	rest	rest	rest	rest	rest	rest	rest
	Sunday	M	rest	rest	rest	rest	rest	rest	rest	rest
		A	rest	FM	FM	rest	FM	FM	FM	rest

Abbreviations: M, Morning; A, Afternoon; PT, physical training (strength training, speed training, interval training, and training on sand); TAC, tactical training; TEC, technical training; FM, friendly match.

Table 2

Repeated sprint ability (RSA) and T-CAR performance outcomes before (pre) and after (post) an 8 week period of preseason training in under-15 (U-15) and under-19 (U-19) soccer players.

Performance	Groups	Pre Mean ± SD	Post Mean ± SD	Within-group changes Δ%	ES (descriptor)	Qualitative Inference
RSA_{best} ($m \cdot s^{-1}$)	U-15	5.58 ± 0.17#	5.81 ± 0.16#*	4.2 (3.1to 5.3)	1.26 (Large)	100/0/0
	U-19	5.90 ± 0.14	6.06 ± 0.15*	2.7 (1.3 to 4.2)	1.08 (Moderate)	99/1/0
RSA_{mean}($m \cdot s^{-1}$)	U-15	5.31 ± 0.09#	5.58 ± 0.10#*	5.0 (4.4 to 5.7)	2.68 (Very Large)	100/0/0
	U-19	5.59 ± 0.17	5.77 ± 0.11*	3.2 (1.3 to 5.0)	0.96 (Moderate)	99/1/0
$PV_{T\text{-}CAR}$ ($km \cdot h^{-1}$)	U-15	15.73 ± 0.84#	16.98 ± 0.68#*	8.0 (5.8 to 10.2)	1.39 (Large)	100/0/0
	U-19	17.45 ± 0.85	18.34 ± 0.91*	5.0 (1.3 to 5.0)	0.94 (Moderate)	100/0/0

Columns: # denotes significant differences between age groups before (pre) and after (post) the preseason period.
*Rows: * denotes significant differences within age groups over time ($p < 0.05$).*

Table 3

Differences in change observed in repeated sprint ability (RSA) and T-CAR performance outcomes for U-19 compared with U-15 soccer players.

		ES (90% CI)	Rating	Percent chance of higher/trivial/lower effects	Qualitative inference
RSA_{best} ($m \cdot s^{-1}$)	U-19 vs U-15	-0.35 (-0.77 to 0.07)	Small	2/26/72	Possibly
RSA_{mean} ($m \cdot s^{-1}$)	U-19 vs U-15	-0.53 (-1.06 to -0.01)	Small	1/12/87	Likely
$PV_{T\text{-}CAR}$ ($km \cdot h^{-1}$)	U-19 vs U-15	-0.37 (-0.70 to -0.05)	Small	0/18/82	Likely

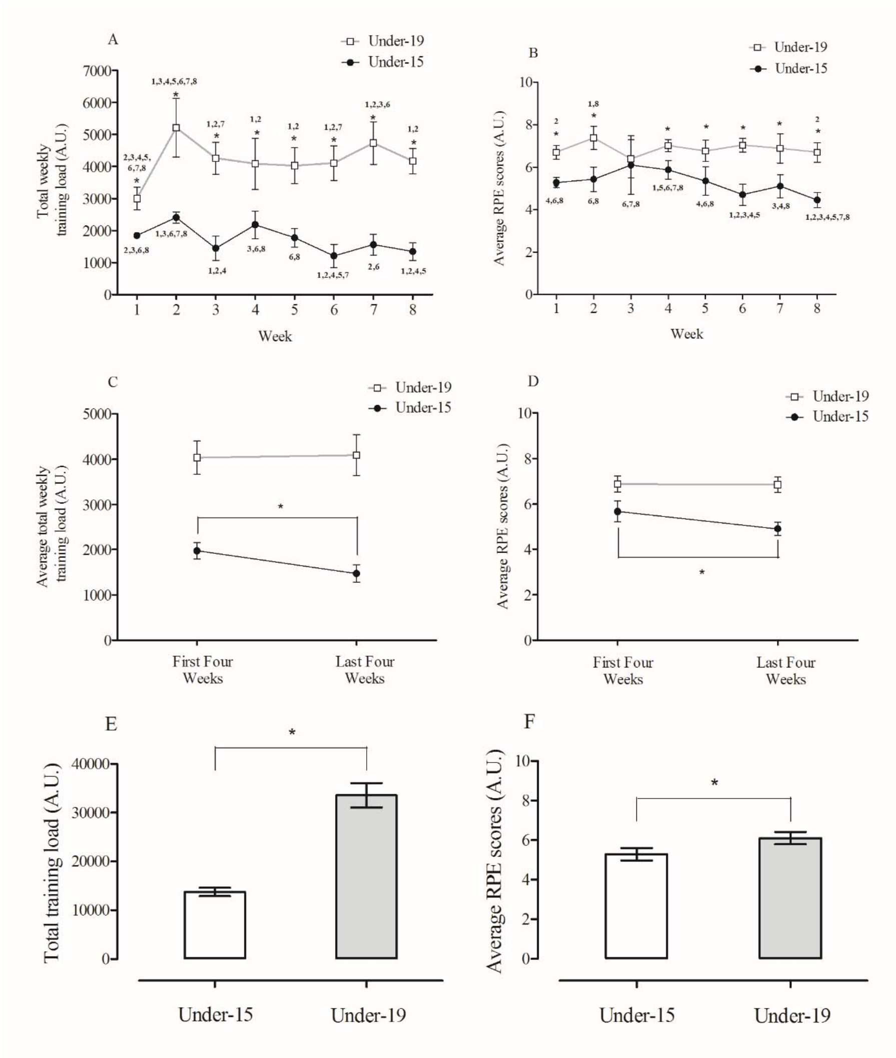

Figure 1

Total weekly training load and average session-rating of perceived exertion (RPE scores) per week (A and B, respectively; upper panel), averaged every four weeks (C and D, respectively; middle panel), and accumulated over 8 weeks (E and F, respectively, lower panel) during the preseason training period in U-15 and U-19 soccer players. Abbreviation: A.U., arbitrary units.
1, 2, 3, 4, 5, 6, 7 and 8 = indicates significant difference from week 1, 2, 3, 4, 5, 6, 7 and 8, respectively.
 # denotes significant differences between the first and the last four weeks ($p < 0.001$);
** denotes significant differences between competitive age groups ($p < 0.001$)*

Discussion

In the present study, we investigated the internal training loads undertaken by U-15 and U-19 soccer players pertaining to the same professional team during 8 weeks of the preseason and the differential responses of the teams regarding the RSA and T-CAR changes. As hypothesized, our results demonstrated that the training loads (volume and intensity) imposed on the soccer players significantly increased from middle adolescence to late adolescence/early adulthood within the same elite development program. Our major finding showed that U-15 soccer players displayed superior gains in RSA and T-CAR performances than U-19 players. Thus, strength and conditioning coaches should be aware that the higher training loads accumulated by U-19 soccer players do not necessarily translate into superior performance adaptations in soccer-specific high-intensity or maximal running tasks. Based on this, our second hypothesis was not confirmed. Furthermore, it was possible to highlight the sensitivity of these field tests (RSA [6 x 20 + 20 m] and T-CAR) to track training-induced changes in two distinct and soccer-specific physical abilities (i.e., repeated-sprints ability and intermittent endurance running performance) during a preseason in youth players of different competitive age categories.

Attempts to evaluate the training load by age groups in talented soccer players during adolescence have been poorly described (Gabbett et al., 2014; Wrigley et al., 2012), especially during the preseason phase. In the present study, we demonstrated that U-15 players had a lower total weekly training load than their older counterparts (U-19) during the 8-week preseason. Wrigley et al. (2012) also reported age-related increases in the training load placed upon youth soccer players (U-14, U-16, and U-18) in a short in-season period (2 weeks). In contrast to our findings, Wrigley et al. (2012) did not report on significant differences in RPE responses (i.e., training intensity index) across age groups. Overall, our data indicate that from U-15 to U-19 age groups, there was not only progression in the total training load, but also in the activity intensities (Figures 1e and 1f, respectively), in accordance with the long-term development model, respecting the biological traits of the athlete to maximize athletic development while minimizing the risk of overtraining and injury (Ford et al., 2011). A recent study confirmed this fact showing that the higher physiological loading placed on U-17 and U-19 compared to U-15 players was probably related to the use of frequent game-like situations (requiring higher power and speed demands) and less time spent learning technical skills and basic tactical principles during training sessions (Abade et al., 2014).

In general, the emphasis during the preseason is on rebuilding physical performance after detraining that occurs during the off-season (Malone et al., 2015). As a result, high training loads are expected during this phase of the season, emphasizing training methods targeting at physical abilities considered relevant to the sport. In the present study, the highest training load was observed in week 2 for both age groups (U-15 and U-19). For U-15 players, the average total weekly training load and RPE scores within the first four weeks (1970.35 ± 178.69 AU and 5.67 ± 0.46 AU) were significantly ($p < 0.001$) higher than those obtained in the last four weeks (1472.16 ± 193.35 AU and 4.90 ± 0.30 AU) of the preseason. These results are in agreement with previous studies involving other team sports showing that players undergo the highest training loads within the first weeks of the preseason (Miloski et al., 2015; Oliveira et al., 2013). On the other hand, no significant difference ($p > 0.05$) was observed for the average total weekly training load or RPE score between the first (4034.39 ± 368.59 AU and 6.87 ± 0.35 AU) and the last (4088.18 ± 450.06 AU and 6.85 ± 0.34 AU) of the four weeks of the preseason for the U-19 age group. This "even" pattern of loading has also been observed in other teams (Nakamura et al., 2016). It remains to be established in the future if "even", "ascending" or "descending" loading patterns during preseasons induce different physical adaptations in soccer players.

Our findings evidenced *very likely* to *almost certainly* improvements in both RSA_{best} and RSA_{mean} (moderate to very large ES) after an 8-week typical soccer preseason in players of different age categories. These RSA improvements are in agreement with those reported in previous studies after standardized training regimens, such as repeated sprint and aerobic interval training (Buchheit et al., 2010b; Ferrari Bravo et al., 2008), strength training (Buchheit et al., 2010a), and small-sided games (Buchheit et al., 2009). The aforementioned studies reported positive changes in RSA_{best} (2.1 to 3.5%) and RSA_{mean} (2.5 to 3.9%) after 4 to 10 weeks of different types of training. The results of the present study are in accordance with these previous studies showing that improvements in RSA_{mean} (3.2 to 5.0%) tend to be slightly superior to those seen in RSA_{best} (2.7 to 4.2%), even though it is known that training-induced changes in both RSA_{best} and RSA_{mean} may be attributed to improvements in similar mechanical aspects (e.g., acceleration) (Buchheit et al., 2009).

The changes in repeated-sprint running performance in this study are also likely to be explained by a variety of alterations in the anaerobic metabolism (Spencer et al., 2005) and neuromuscular components (Girard et al., 2011). According to the literature, 8 weeks of the soccer preseason can be sufficient to improve anaerobic ATP production, phosphocreatine resynthesis, and/or blood buffering capacity (Iaia et al., 2015; Spencer et al., 2005). In team sport athletes, maximization of RSA has also been linked to the ability to develop maximal speed (Iaia et al., 2015). For instance, Buchheit et al. (2009) reported moderate correlations (r = 0.37 to 0.40; $p < 0.05$) between changes (Δ) in 10-m sprint time and RSA performance outcomes after a training program in handball players. Of interest, tactical and technical training applied in both categories (U-15 and U-19) during the preseason also consisted of small-sided games, which in turn involved performing soccer-specific movements, such as changes of directions, acceleration, and deceleration. Thus, it is likely that the ability to quickly change the direction while running at maximal speeds may also have played a role (Young et al., 2001).

It has been suggested that improvements in intermittent endurance running performance should be emphasized during the early preparatory phases of the training plan since no additional adaptation/gain in the ability to perform intermittent exercise is expected during the in–season period (Krustrup et al., 2003; Oliveira et al., 2013). During the 8-week preseason of this study, T-CAR performance assessed by the $PV_{T\text{-}CAR}$ increased by about 8.0% and 5.0% for the U-15 and U-19 soccer players, respectively. These relative changes are comparable to those previously reported by Fernandes da Silva et al. (2015) who found an improvement of 7.7% and 5.4% in the $PV_{T\text{-}CAR}$ after two types of aerobic training (shuttle vs. straight-line runs) in junior soccer players (age: 17.9 ± 1.0 years). In addition, standardized differences observed in the current study (ES: 1.39 and 0.94 for U-15 and U-19, respectively) are in fact similar to changes in both Yo-Yo IR1 (ES: +1.2) and 30-15 Intermittent Fitness (ES: +1.1) tests after an 8-week training intervention (Buchheit and Rabbani, 2014), thus highlighting that T-CAR has sensitivity comparable to other traditional field tests to detect training-induced adaptations in the intermittent endurance running capacity of youth soccer players.

Some studies have previously suggested positive associations between the heart rate-based training load and changes in different aerobic fitness measures (Manzi et al., 2009, 2013). In contrast, other studies have shown that the RPE-derived training load and subsequent adaptations in aerobic fitness variables are poorly correlated (Akubat et al., 2012; Arcos et al., 2015). Similarly, no significant correlation was obtained in the present study between the RPE-based total training load and anaerobic-aerobic performance adaptations in each age category. However, when data from both age categories were pooled, there was a significant and moderate negative correlation between changes in RSA_{mean} and the RPE-based total training load (r = -0.36; $p = 0.05$). In agreement with this finding, Arcos et al. (2015) also showed a negative relationship (r = -0.54 and -0.64; $p < 0.05$) between training volume (min) and changes in sprint running performance (i.e., 5 m and 15 m times). From a practical point of view, these findings highlight the importance that coaches and strength and conditioning professionals should attach to monitoring the perceived training loads individually in young athletes, especially to avoid/reduce the occurrence of maladaptations in physical performance measures associated with excessive loading during the preseason phase.

In line with this viewpoint, a novel finding of the current study was that the U-15 age group, despite accumulating a lower weekly training load throughout the study period, displayed higher improvements in $PV_{T\text{-}CAR}$,

RSA_{best}, and RSA_{mean} than U-19 soccer players (Table 3). Despite the greater gains in performance during the preseason phase, it should be highlighted that the performance level of younger players in the T-CAR and RSA tests at the end of the preseason was still lower than the performance level reached by their older peers at the beginning of the preseason. This is the first study showing that crucial soccer match-related physical fitness abilities, such as $PV_{T\text{-}CAR}$ and RSA, are optimized in different magnitudes of adaptation in well trained U-15 and U-19 players after a regular training process without any external manipulation. In general, our findings are consistent with the results presented by Behringer et al. (2011) in a meta-analysis showing a negative correlation (r = -0.25; p = 0.02) between the participant's age and the magnitude of change for three physical performance abilities (throwing, jumping, and running) following resistance training programs in physically active children and adolescents. In the same study, Behringer et al. (2011) also showed that youth non-athletes presented greater enhancements in physical abilities than highly trained athletes. This indicates that younger boys during adolescence, especially around the peak height velocity (Meylan et al., 2014; Philippaerts et al., 2006), may experience higher gains in physical and motor performance than their older counterparts. From this perspective, our findings indicate that there might be a ceiling effect of functional adaptations in older players, requiring higher training loads to obtain lesser gains in physical performance in the RSA and T-CAR.

Practical Implications

The current study showed that total weekly RPE-based training loads varying between 1000 and 2000 AU for U-15 and ≈ 4000 AU for U-19 soccer players can provide a sufficient stimulus to induce positive gains in RSA and intermittent endurance running performance during a preseason period. Coaches and strength and conditioning professionals should be aware that $PV_{T\text{-}CAR}$, RSA_{best} and RSA_{mean} are trainable, but to different magnitudes of adaptations, in U-15 and U-19 soccer players. Such findings should assist coaches to optimize the timing of training programs designed to improve these two crucial soccer-specific physical abilities, taking into account the differences in age-related responsiveness. In addition, our findings demonstrated the sensitivity of these two field tests (T-CAR and RSA [6 x 20+20 m]) to identify important training-induced adaptations in soccer players of different competitive age categories.

Conclusions

In conclusion, our findings indicate that U-19 soccer players had a higher training volume and perceived the training sessions as heavier than U-15 players. Consequently, older players accumulated a greater total training load throughout the preseason phase than U-15 soccer players. Changes in $PV_{T\text{-}CAR}$ and RSA performance outcomes were *very likely* to *almost certainly* beneficial after the preseason period in both competitive age categories, having U-15 players achieved relative gains *possibly* to *likely* greater in high-intensity and maximal running performances than U-19 soccer players.

Acknowledgements

We would like to thank for the patience and cooperation of the athletes and coaches during the execution of this study and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financial support.

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