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Original Article (short paper)

Match internal load in youth elite soccer players is period, playing position and intermittent running capacity dependent

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Abstract — **Aims:** The aims of this study were: i) to verify whether player internal load (PIL) monitored via heart rate (HR) varies with game-time and playing position; ii) whether intermittent running capacity (IRC) is related to the maintenance of within-match PIL in elite youth (U-15) soccer players. **Method:** Twenty-one elite soccer players (14±0.5 yrs, 172±7 cm, 63±6 kg) had their heart rate monitored (beats/min) in five matches and were tested twice for IRC (Yo-YoIR2, distance [m]) over a seven-week competitive season. Percentage of maximal heart rate (%HR_{max}) and time spent (TS%) in five zones (Z1[<70%]; Z2[71-85%]; Z3[86-90%]; Z4[91-95%] and Z5[>96%]) were our PIL indexes. Data from three complete games in the same position of each player were analyzed and matches halves, time intervals (T1 to T6), and playing positions (fullbacks, central defenders and forwards [N=5 each], midfielders [N=6]) were compared, and the relationship between IRC and within-match PIL was determined. **Results:** PIL was higher in 1st (86±3%) than in the 2nd half (84±4%; $p<.001$). The 2nd half had more TS% in Z1 and Z2 ($p<.05$). PIL in T4 was the lowest ($p<.01$), and in T6, it was lower than T1 and T2 ($p<.01$). Fullbacks and midfielders showed higher PIL and higher TS% in Z4 ($p<.05$) than the other positional roles. The average IRC correlated with PIL in T6 (r=.56, $p<.01$) only. **Conclusion:** In conclusion, the internal load in elite youth (U-15) soccer players varies with game-time and playing position; and their IRC is related to the maintenance of within-match PIL.

Keywords: match demand; soccer; exercise intensity; fatigue; positional role.

Introduction

The workload of athletes is categorized as "external" (i.e., work performed) and "internal" loads (i.e., psychophysiological response to work performed). While time–motion analyses are adopted for monitoring external load during match-play, heart rate, blood lactate, the perception of effort and training impulse are used to follow internal load[1]. From a practical point of view, the measurement of heart rate (HR) is an objective, noninvasive and accessible method for monitoring player internal load (PIL). Moreover, HR is currently the most used physiological variable for monitoring contemporary training load1, including soccer training, particularly during small-sided games (SSGs)[2,3].

Player internal load in competitive soccer match-play is shown to be between 165-175 beats.min^{-1}, that is 80-90% of their maximal HR value (%HR_{max}), in male adult players[2,4,5]. However, little attention has been given to PIL quantification in younger soccer players[6-8]. Thus, considering the difficulties to quantify true dose-response nature of match-play[9], comparing HR with external load measures derived from modern time-motion devices (e.g. GPS and accelerometer) as well as with other regular intermittent running performance tests (e.g. Yo-YoIR2) is of interest in the field of sports science.

Dissociation between external and internal load may reveal the athlete's state of fatigue[1]. Then, in-game performance characteristics, physical capacity to endure high competitive demands and congested schedule may discriminate between elite and sub-elite players[8,10]. Fatigue in soccer players has transient characteristics during the game[11], and it has been shown that some physical performance variables are reduced in the second half[2,11,12]. This reduction is accentuated mainly in those related to high-intensity running, and sprint being position-dependent[11]. Based on the aforementioned points, investigation of whether intermittent running capacity (IRC) obtained in a traditional intermittent protocol used for assessing soccer players (i.e. Yo-YoIR2) is related to the maintenance of high HR in young soccer players is merited. In addition,whether a high IRC obtained from such test is related to the performance of soccer players at certain stages of the match is unknown.

Cultural differences exist across professional soccer leagues and differences in physical and technical aspects of match-play are evident[13]. In this way, the playing position, a lower tactical understanding of specific tasks, and the style of play might influence the internal load in young players as it does in adults. In addition, external match-play load in young soccer players may have particular characteristics as they show high aerobic energy contribution to intermittent exercise in activities such as running and walking compared to adults[14]. Furthermore, factors such as shorter stride length, high stride frequency, and faster rate of stride relative to body size compared to adults contribute to a greater relative physiological internal load or effort intensity in youth[15,16] and this may not correspond to the external load observed. For these reasons, there is a need for studies on young players workload monitoring. Appropriate training stimulus and its control is of relevance to optimize the players' performance and prevent overtraining. Moreover, the understanding of internal load may culminate in harmonious athletic development and minimize the risk for nonfunctional overreaching, injury and illness.

Therefore, the aim of this study was twofold: i) to verify whether PIL monitored via HR varies with game-time and playing position; and ii) whether IRC is related to the maintenance of within-match PIL in young (U-15) soccer players.

Methods

Design

In this analytical non-experimental, cross-sectional study, two methodological approaches were used. Firstly, the internal load demand of a group of soccer players was monitored during an U-15 competition in Minas Gerais, Brazil. In this approach, we evaluated young soccer players in an official match-play situation. Heart rate was recorded and used as a PIL index because of its viability, lower cost and usually available technological device to monitor physiological training load in the youth category context (i.e., HR team equipment). Heart rate (beats/min) of each player was recorded during five league soccer matches over a seven-week competitive season. Subsequent analyzes were established for temporal (half and match time intervals) and playing position comparisons. The second approach aimed at correlating IRC measured via an intermittent running protocol (i.e. Yo-YoIR2)[17] with PIL measured via HR. The Yo-YoIR2 protocol was selected because of its time-efficiency and usefulness for high-level soccer players.

The monitored matches were selected according to competitive similarity (i.e. within the first three positions in the classification table). Such criteria are known to influence player work-rate in the overall or transient match time intervals[18]. Since team formation substantially influences position-specific physical and technical demands[19], only matches in which both teams employed a 4-4-2 system (four defenders, four midfielders, and two forwards) at the beginning of match-play and the opposite team played either a 4-4-2 (70%) or a 4-3-3 (30%) system were selected. Only HR data from players who participated in three complete matches in the same playing position were used for the final data analysis. In order to make comparisons with the available literature, the PIL was expressed as a percentage of the maximal heart rate ($\%HR_{max}$), in detriment of HR reserve which is seen as more adequate[2]. However, such choosing is justified since $\%HR_{max}$ has been broadly employed in different studies on official and friendly match-play[2].

Subjects

Twenty-two youth male soccer players from two teams participating in an official competition organized by the *Federação Mineira de Futebol* (FMF) agreed to take part in this study after parental consent being obtained. One player (a midfielder) withdrew from the study due to injury. Twenty-one players (age 14 ± 0.5 years; height 172 ± 7 cm; body weight 63 ± 6 kg) represented by fullbacks (FB; N=5), central defenders (CD; N=5), midfielders (MD; N=6), and forwards (FW; N=5) participated in this study. The goalkeepers' HR data were excluded from the study as they are not subjected to the same workload as the outfield players.

All players were engaged in regular training programs (1.5 h/session, 1 session/day, 5 days/week), and played one official match per week either on Saturday or on Sunday. Eighty percent of the training session duration aimed at technical and tactical skill development. The integrative tactical-technical-physical training sessions were performed twice a week and included: aerobic (e.g. large-sided games [GK+6 to 8 vs. 6 to 8+GK], small-sided games [3 to 5 vs 3 to 5] and low-to-moderate intensity runs), anaerobic stimulus (e.g. maximum sprint and high-intensity runs); and strength (e.g. plyometrics). No supplemental training (e.g., resistance training) either in season or off-season was performed. All volunteers had 4 ± 1 years of experience in systematic soccer training and competition. The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of Universidade Federal de Viçosa (Of Ref n° 046/2007).

Procedures

The subjects followed the diet proposed by their respective club and were instructed to refrain from caffeinated substance (e.g. matte tea, chocolate, coffee, *guaraná* and coke drinks) consumption 24 hours prior to IRC tests and match-play. One week before the competition period, the players had their IRC assessed using the Yo-YoIR2 test. The second evaluation took place on Wednesday preceding the fourth game. The tests were performed in the afternoons (i.e. 14h -16h) to simulate the time of the day where the matches occurred. It was performed at the beginning of each training session, after a 20-min typical warm-up. The players wore the playing kit as in the games and the tests were performed on natural turf. The recommendation to reduce training load 48-hour prior the tests[17] was followed. The players were randomly distributed among tests and were verbally encouraged to perform their maximum effort.

Prior to match-play, players performed a standard 25-min warm-up session (~75% %HR_{max}) which included light-jogging, dynamic stretching, technical drills, and repeated short high-intensity drills. Then, the coach provided the final tactical and motivational instructions in the dressing room before the kick-off. During the half-time interval, the players stayed passive (seated) for resting whilst receiving technical/tactical instructions. The standard club nutritional guideline was followed during a half-time interval (e.g. conventional sports drink [200–300 mL] or gel [2 sachets of 23 g glucose and maltodextrin]). During the matches, players had water *ad libitum*. All matches were played between 13h30min and 15h00min (24 ± 3°C; RH= 65 ± 10%) on natural turf pitches of official dimensions (105x68m).

Data collection and processing

All subjects were familiarized with the HR monitors during the training sessions. The permission to use HR monitors during the matches was previously obtained from the Referee's Committee of the above mentioned FMF. Each player used a strap equipment component of Polar Team System® (Polar Electro Oy, Kempele, Finland). HR was recorded every 5 seconds and expressed in relation to maximum or peaked HR (%HR_{max}) during matches, training sessions, and Yo-YoIR2. The use of %HR_{max} obtained in such situations is considered a valid strategy to obtain high HR values[6,20,21]. In order to compare in-game transient internal load, three equal time intervals of ~ 11 min in each half (first half: T1-T3; second half; T4-T6) were determined. Percentage of time spent (TS%) in each one of the five PIL zones of the HR_{max} (Z1[<70%]; Z2[71-85%]; Z3[86-90%]; Z4[91-95%] and Z5[>96%]) was also determined in each match-play half for comparisons[5].

Statistical analysis

Data are expressed as means ± SD. Non-parametric testing was performed due to non-homogeneity of variances of the dataset. Wilcoxon test was used for comparisons between 1st and 2nd half and for each pair of six equal intervals of match-play (T1 to T6). The four positional groups were compared using Kruskal Wallis test. When a significant positional effect was found, Welch test was used to isolate the differences between each pair. The effect size (ES) of *g* (unbiased estimate of Cohen's *d*) was calculated to quantify the magnitude of the difference between halves, time intervals and playing positions. The criteria for interpreting ES were 0.0–0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; 2.0–4.0, very large; >4.0, extremely large[22]. Pearson's correlation was used between individualized PIL (%HR_{max}) and IRC (Yo-YoIR2 test). The following criteria were adopted for interpreting the magnitude of correlation (r): ≤.1 trivial; >0.1–0.3 small; >0.3–0.5 moderate; >0.5–0.7 large; >0.7–0.9 very large; and >0.9–1.0 almost perfect[23]. The significance level was set at $p<.05$.

Results

The analyzed matches presented an average value of 85 ± 4%HR_{max}. The PIL value in the 1st half (86 ± 3%HR_{max}) was higher than that in the 2nd half (84 ± 4%HR_{max}) with a moderate magnitude of the difference (Fig. 1; $p<.001$; ES=1.23).

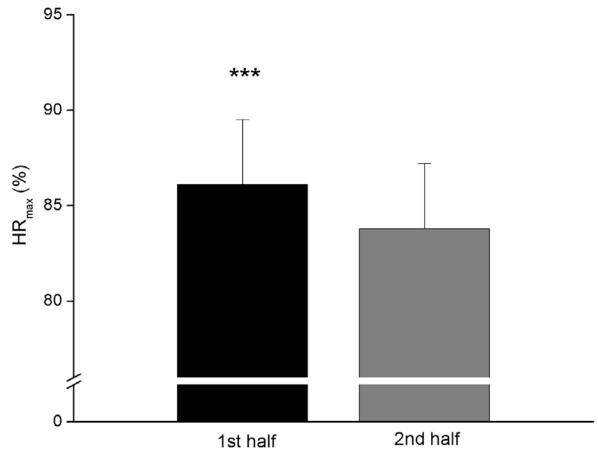

Figure 1. Player internal load (PIL) expressed as percentage of individual maximal or peak heart rate during official match-plays in youth soccer players (n=21). Data are presented as mean ± SD.
*** denotes significant difference vs. 2nd half ($p<.001$).

Figure 2 shows temporal variations in %HR_{max} across different match-play time intervals. In the 1st half, the PIL had no temporal variation (T1 to T3; $p>.05$). However, at the beginning of the 2nd half (T4) the PIL was lower than those in T5 ($p<.01$; ES=.92) and T6 ($p<.01$; ES=.71); and those in the T1 to T3 (ES = 1.12-1.57). In the final stage of the match-play (T6), the PIL showed lower rates than those in the first stages ($p<.01$; T1 ES= .82 and T2 ES=1.02).

Concerning the TS% in defined %HR_{max} zones (Fig. 3), in the 1st half players stayed more time in high PIL zones: Z4 ($p<.04$; ES=.70) and Z5 ($p<.03$; ES=.60), as compared to other zones. In the *2nd* half, players spent more time in low PIL zones: Z1 ($p<.01$; ES=.92) and Z2 ($p<.03$; ES=.76) than in the other zones. No difference between halves was observed for the values of TS% in Z3 (p=.41).

The PIL values in different playing positions during the matches are presented in Table 1. FB exhibited higher %HR_{max} compared to CD and FW. The FW and CD players spent more time in the low PIL zones (i.e., Z1 and Z2) than MD and FB. The FW and MD had higher TS% in Z4 compared to CD and FW.

The average IRC obtained in the Yo-YoIR2 test was 745 ± 127m. A positive correlation was found between IRC and PIL (%HR_{max}) in T6 (r=.56; p=.008). No other significant correlation was observed (r range of -.27-.31).

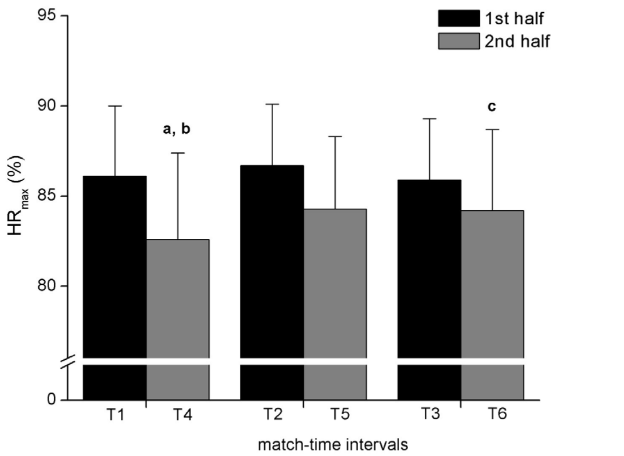

Figure 2. Player internal load expressed as percentage of individual maximal heart rate in different match-time intervals during official games in youth soccer players (n=21). Data are expressed as mean ± SD.
a, denotes significant difference vs. all fist half time match intervals ($p<.001$); **b,** denotes significant difference vs. T5 and T6 ($p<.01$); **c**, denotes significant difference vs. T1 and T2 ($p<.01$)

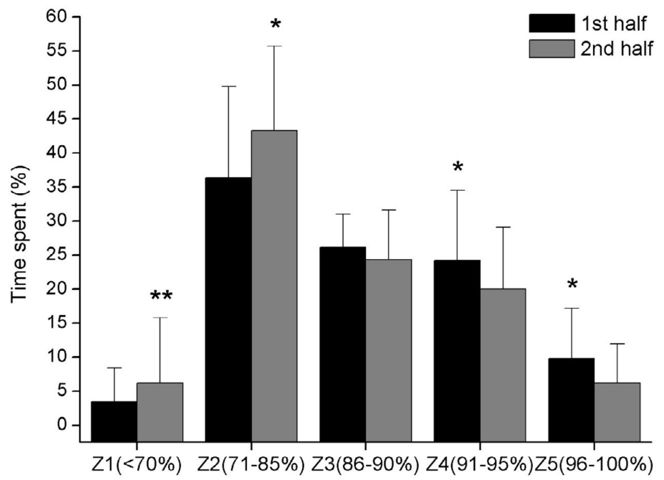

Figure 3. Time spent in five player internal load zones. Player internal load expressed as a percentage of maximal heart rate during official match-plays in youth soccer players (n=21). Data are mean ± SD.
*, **, denotes significant difference vs. other half at $p<.05$ and $p<.01$ levels, respectively.

Table 1. Player internal load expressed as a percentage of maximal heart rate and time spent in five zones from each playing position during official match-play in youth soccer players.

PIL	Players' Position				*p value*	*post hoc* test and effect size (ES)
	FB (N=5)	CD (N=5)	MD (N=6)	FW (N=5)		
$\%HR_{max}$	88.0 ± 1.5	82.0 ± 4.5	86.9 ± 1.8	82.4 ± 1.8	p = .004	FB>CD*(1.42); FB>FW***(3.00); MD>FW**(2.20)
Z1(%)	0.6 ± 0.7	9.8 ± 12.5	1.4 ± 1.3	8.1 ± 3.3	p = .022	FW>FB**(2.13); FW>MD**(1.91)
Z2(%)	30.5 ± 8.5	48.2 ± 6.8	34 ± 10.5	47.8 ± 8.1	p = .013	CD>FB**(2.04); FW>FB**(1.88); CD>MD*(1.48); FW>MD*(1.37)
Z3(%)	29.0 ± 4.3	21.6 ± 6.4	26.4 ± 3.4	23.4 ± 2.5	p = .117	
Z4(%)	29.0 ± 5.3	15.4 ± 7.0	27.1 ± 7.4	15.9 ± 6.8	p = .009	FB>CD**(1.91); FB>FW**(1.92); MD>CD*(1.47); MD>FW*(1.45)
Z5(%)	10.8 ± 5.2	4.9 ± 2.5	11.0 ± 6.8	4.7 ± 4.4	p = .072	

Data are mean ± SD. PIL= player internal load; $\%HR_{max}$= percentage of individual maximal or peak heart rate; Z1 to Z5 indicate time spent (%) in each one of five PIL zones of $\%HR_{max}$ (Z1[<70%]; Z2[71-85%]; Z3[86-90%]; Z4[91-95%] and Z5[>96%]); FB=fullbacks; CD=central defenders; MD=midfield; FW=forwards; *p value* obtained of Kruskal Wallis test; *, **, ***, denotes significant difference at $p<.05$, $p<.01$ and $p<.001$ levels, respectively; *post hoc* by Welch test and effects size (ES) from *g* (unbiased estimate of Cohen's *d*).

Discussion

The analysis of performance in the real match-play situation is a pertinent way to determine whether an athlete is adapting to their training program or is at risk of non-functional overreaching. Moreover, real match-play workload information serves to coaches routinely monitor how the athlete reacts in the competitive scenario. In this study, we employed a method of high ecological validity to measure player internal load (i.e. HR) in matches of an official soccer competition of the U-15 category and tested the players' IRC. Our results indicate that the internal load in elite youth soccer players varies with game-time and playing position; and that their IRC is related to the maintenance of within-match PIL.

A range of 80–90% of HR_{max} is expected in soccer games, independently of playing level and category[2]. Our results confirm that in youth groups competitive soccer matches are played at high-internal load zones interspersed with sporadic moments (~ 4% of match-play time) of low-to-moderate zones (i.e., $70\%HR_{max}$). Such values are also reported for adult professional players[4,24]. In the present study, the analyzed matches were performed on official pitches. Therefore, the larger playing area could have led young soccer players to perform a high stride frequency and faster rate of stride relative to body size[15,16].

Elite youth Brazilian players U-15 showed higher average internal load than U-17 and U-20 when the time played was corrected by meters per min[25]. Although in this study the PIL indexes did not vary significantly within the 1st half, the frantic nature of play at the beginning of games to impose one's presence on the opposite team[26] could also help to explain the high PIL math average. Indeed, previous studies have shown a temporal difference in work-rate expressed in the opening 15 min of match-play[27,28]. Such a match period has been characterized as the most frantic and intense due to an assertive tactical strategy, pre-match motivational instructions, and player arousal[29].

On the other hand, we observed a lower internal load in the early stage of the *2nd* half. Such result may be due to the passive (i.e. resting) players' behavior during the half-time interval. The physiological reasons for soccer players' transient fatigue during the match are not clearly defined[24,29-31], and in youth players, this issue warrants future studies. Despite that, no difference in internal load between halves was found in European players of similar age groups[6,7]. Nevertheless, the differences in methodological design, player levels and metrics used to determine PIL make it difficult to compare studies.

The player's workload in official soccer match-play is highly dependent on positional role[2,6,26]. In the present study, we observed that FB exhibited higher internal load compared to CD and FW players. This finding confirms the Brazilian FB work-rate characteristics inasmuch as this positional role in the Brazilian soccer is performed by players engaged in constant tactical tasks (i.e., accentuated out ball actions)[25,32]. For instance, the higher TS% in the higher zone (>90%HR_{max}) showed by the FB is similar to that observed in U-17 and U-20 Brazilian players[33]. These results indicate a different style on the positional role in youth categories in Brazil. Moreover, this finding may help to explain why Brazilian soccer players have gained international prominence in this position over the years (i.e., Cafú; Roberto Carlos; Daniel Alves; Marcelo) mainly due to their great physical ability to maintain high match-play work-rates.

Regarding the importance of running sprint ability for engaging in high internal load events during match-play, we observed a largely positive relationship between PIL at end of the 2nd half and performance in Yo-YoIR2 test, which confirms the previous findings[34]ÿ. Such correlation suggests that the reduced PIL in the 2nd half is dependent upon players' fitness. That is, fitter players can spend more time in high-zones of HR and show lower performance reduction in the *2nd* half, especially in the final stages of the match-play. A high correlation between IRC and TS% above 85%HR_{max}, measured by Yo-YoIR2, and association of TS% with sprinting and high-intensity activities (13.0 to 18.0 $km.h^{-1}$) during youth soccer match-play has been reported[34,35]. This evidence gives support to the use of IRC as an alternative metric to associate external and internal load. The use of more expensive equipment like GPS and accelerometer is not always the best strategies. This can be further reinforced by the recent study by Sparks, Coetzee, Gabbett[36]. They showed only a small correlation (<.3) between external load (i.e. velocity zones intensity and accelerometer data Player Load®) and Yo-YoIR1-derived HR thresholds for match-play monitoring.

Performance in intermittent physical exercise may reflect players' conditioning and their ability to cope with physical engagement during the late stages of a match-play[6,37]. This inherent soccer specific-fatigue has important implications for prescribing training to improve this remarkable feature of players. From a practical point of view, high-interval training, large or small-sided games (SSGs) could be used to improve the ability for repeating high-intermittent efforts demanded in the game situation. A previous study has showed that SSGs can provide an adequate training stimulus for young players and are feasible for groups with heterogeneous maturation levels[3].

This study has some limitations. First, only two teams were analyzed. Unfortunately, studies on sports training face a number of factors that affect sample size including small squad sizes, player compliance, injuries, and different training program. Second, we did not control substitutions and regulations (i.e. 5 substitutions) which could induce some bias in PIL measurements, though it reinforces the ecological validity of measurements. Despite the fact that percentage of reserve HR (%HR_{res}) appears to be more reliable[2,38] to measure internal load in athletes, the expression of %HR_{max} eliminates the difficulty in measuring resting HR (i.e., at wake up stay 10-min laid on a bed in a calm environment with closed eyes)[2] when players by themselves should use similar procedures. No measure of perceived exertion (e.g. RPE) was performed because it seems to be incompatible with the competitive match dynamics and biased information could be produced. Besides that, subjective measures could only reflect the psychological readiness of an athlete to perform.

Future studies using GPS devices and accelerometer with their derived indexes are encouraged in an attempt to help to describe and to compare patterns of movements in different soccer categories and competitive levels, tactical interactions, shapes, and game styles. In addition, studies investigating acute adaptive processes regarding the post-game kinetics of fatigue are also needed. Moreover, to analyze the effects of soccer training in order to enlighten the development of young players is of interest.

Finally, the differences observed in most of the comparisons made in our study are of moderate magnitude. However, it is of relevance for training specificities when the objective is to prepare the player to undertake high-intensity actions in early stages of the 2nd half and at the end of the match. A player more tolerant to fatigue could respond to higher-intensities actions on transiently decreased work-rates during or in the latter stages of a match-play.

Conclusion

In conclusion, the internal load in elite youth (U-15) soccer players varies with game-time and playing position; and their IRC is related to the maintenance of within-match PIL. Such findings are of practical relevance as they may assist coaches in improving their training design and strategies to control competitive workload.

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