# The within-participant Correlation between s-RPE and Heart Rate in Youth Sport

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## ABSTRACT

The monitoring of training load is important to ensure athletes are adapting optimally to a training stimulus. Before quantification of training load can take place, coaches must be confident that the tools available are accurate. We aimed to quantify the within-participant correlation between the session rating of perceived exertion (s-RPE) and summated heart rate zone (sHRz) methods of monitoring internal training load. Training load (s-RPE and heart rate) data were collected for rugby, soccer and field hockey field-based training sessions over a 14-week in-season period. A total of 397 sessions were monitored (rugby n = 170, soccer n = 114 and field hockey n = 113). Within-subject correlations between s-RPE and sHRz were quantified for each sport using a general linear model. Large correlations between s-RPE and the sHRz method were found for rugby (r = 0.68; 95 % CI 0.59–0.75) and field hockey (r = 0.60; 95 % CI 0.47–0.71) with a very large correlation found for soccer (r = 0.72; 95 % CI 0.62–0.80). No significant differences were found between the correlations for each sport. The very large and large correlations found between s-RPE and the sHRz methods support the use of s-RPE in quantifying internal training load in youth sport.

## Introduction

At any sporting level, training involves the manipulation of loads (e. g., intensity and time) to promote positive adaptation (i. e., improved fitness) whilst guarding against potentially negative consequences (i. e., non-functional overreaching, injury and illness) [6]. Increases in training workload, characterised by increases in training volume, intensity and frequency have typically been shown to lead to beneficial adaptations and performance improvement [34]. On the other hand, a "more is better" approach may be too simplistic, with higher training volumes shown to increase the risk of overuse injuries in multiple sports [15, 36].

The above factors are relevant for youth athletes who participate in multiple sports [11] or across multiple age groups and playing standards within a sport [29] leading to an escalated training load. Youth athletes who encounter a high ratio of workload-to-recovery time are at risk of overuse injuries and overtraining with 20 % of school and club level athletes suffering from non-functional overreaching at some point in their sporting careers [28]. Both non-functional overreaching and overuse injuries can lead to burnout and withdrawal from sport, circumventing the potential benefits of sporting participation such as improvements in physical fitness, reduced metabolic disease risk, and development of self-esteem [13]. The "Sport England" organisation recently estimated that 3.83 million 16–25 year olds participate in sport on a weekly basis. Therefore, the appropriate monitoring and prescription of training

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load is as much of an issue for schoolteachers and local club coaches as it is to those coaches working with elite level athletes.

To optimise physiological responses to training, monitoring internal and external training loads has been recommended [23]. External training load represents the work performed by an athlete on the court, field or track (e. g., actions, distance covered, high-speed running), whereas internal training load is the physiological stress response to the external load experienced by an athlete. Individual differences such as physical fitness, training age, genotype, phenotype and playing experience can influence perceptions of session intensity (i. e., internal load) to a given external training stimulus [19]. Consequently, a prescribed training load may prove to be inadequate or excessive for individual athletes within a team sport context, which may result in some athletes under- or over-training. To effectively periodise a training program and ensure intended loads are being achieved at an individual level, coaches must incorporate measures of internal load monitoring within their coaching and training practices.

Before methods of quantifying internal training loads can be implemented into practice, coaches must be confident that the data collection methods accurately represent the internal response of the athlete. Edwards [14] developed the summated heart rate (HR) zone method (sHRz) whereby the training session is divided into the duration spent in five heart rate zones with time in each zone multiplied by a different weighting factor (50–59 % x 1, 60–69 % x 2, 70–79 % x 3, 80–89 % x 4, 90–100 % x 5). The adjusted scores are then summated. Although this method has proven useful in monitoring internal training load [6], a high level of technical expertise is required to collect and collate heart rate information for an entire team. Additionally, the purchase and maintenance of telemetric heart rate systems have large cost implications, confining this method to sports teams or athletes with sufficient financial backing, as opposed to athletes competing below this level, where participation numbers are greater (e. g., school sport).

Foster et al. [18] developed a cost-effective, quick and practical method of quantifying internal training load through the Session Rating of Perceived Exertion method (s-RPE). Large correlations between s-RPE and the sHRz method have been demonstrated within adult professional tennis [20], swimming [37] and male and female soccer [2, 8, 16, 25, 27] but are currently lacking within youth sport athletics. Although such findings appear to suggest s-RPE is an accurate measure of internal training load, only one study in professional soccer [27] has calculated within-participant correlations. Within-participant correlations offer a higher level of statistical precision than calculating correlations for individual players or pooling data by utilising the correct degrees of freedom [3, 5].

Despite the apparent advantages of using the s-RPE method to quantify internal training load, there is currently a scarcity of research investigating the validity of s-RPE in comparison to heart rate-derived training loads in youth sport. At present, research in youth soccer [25] is limited by the lack of within-participant correlation analysis. Therefore, the present study aimed to quantify the within-participant correlation between the s-RPE and sHRz methods of monitoring internal training load in youth sports and to determine the influence of sport (rugby, soccer, field hockey) on the magnitude of the correlation.

## Methods

### Subjects

Twenty-nine adolescent athletes including nine female field hockey (age 16.7 ± 0.8 years, height 164.7 ± 6.4 cm, body mass 60.0 ± 6.3 kg), 10 male rugby union (age 17.2 ± 0.4 years, height 179.9 ± 5.4 cm, body mass 83.6 ± 11.5 kg) and 10 male soccer (age 17.2 ± 0.8 years, height 174 ± 0.05 cm, body mass 73.6 ± 7.1 kg) players were recruited from an independent school in the United Kingdom. All players and parents provided informed written consent prior to participation. Ethics approval was granted by the University's ethics committee with ethical standards meeting those for sport and exercise science research.

### Design

The study used an observational and longitudinal research design, whereby data were collected over a 14-week in-season training period from September to December, 2016. Coaches were instructed to carry out their training sessions as normal with no interference from the researcher.

Each participant was assigned a portable heart rate belt (T31c, Polar Electro, Kempele, Finland) and prior to data collection, participants completed the 30:15 intermittent fitness test whilst wearing their assigned heart rate monitor to elicit a maximum heart rate [7]. Maximum heart rates were required for each participant to calculate individual heart rate zones [14].

All participants typically completed four training sessions per week structured around a competitive mid-week fixture. Due to the unsuitability of heart rate to quantify training load during resistance training [6, 12], only data obtained from field-based training sessions with a clean heart rate trace were analysed. A total of 397 training sessions were observed (rugby n = 170, soccer n = 114 and field hockey n = 113) with a median of 18 sessions per rugby player (range 10–24), 12 sessions per soccer (range 5–18) and 10 sessions per field hockey player (range 4–23). Matches, rehabilitation and gym sessions were not analysed.

### Procedures

Following all field-based training sessions, participants provided an RPE measure as well as a session duration to the nearest minute to the lead researcher. The RPE selection was made non-verbally by pointing to the desired text descriptor on a modified Borg category-ratio 10 (CR-10) scale, in isolation from other participants to avoid external influence on selection. Measures of RPE were taken approximately 30 min following each training session to avoid any influence the activities completed towards the end of each training session had on RPE [18]. The RPE anchor was then multiplied by the session duration to give an s-RPE in arbitrary units.

Participants wore their assigned heart rate monitors throughout all field-based training sessions with heart rate recorded at a sampling frequency of 1 Hz. Following the training session, all participants' heart rate data was downloaded using the software provided by the manufacturer (Catapult Sprint 5.17, Catapult Innovations, Melbourne, Australia). Each file was cut so only data representing the actual training session were analysed, reconciling with session duration. The five heart rate zones were set at 50–59 %, 60–69 %, 70–79 %, 80–89 % and 90–100 % of an individual's max
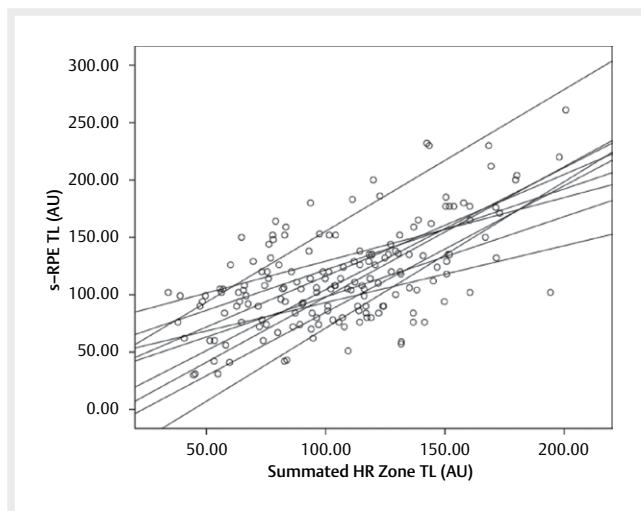
► **Fig. 1** Relationship between s-RPE TL and Summated HR Zone TL for rugby (r = 0.68).
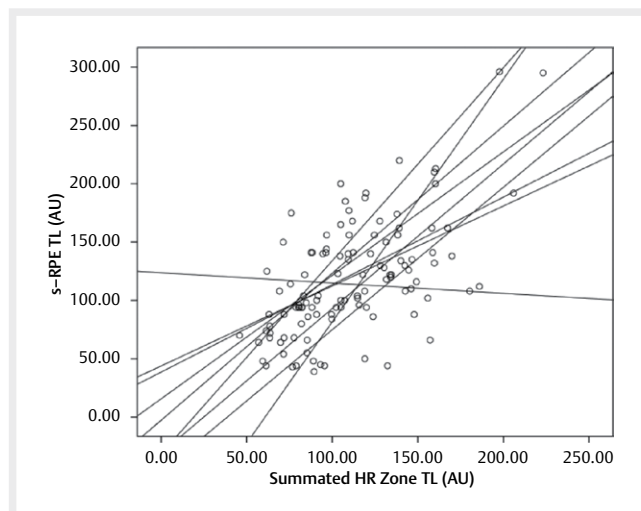


► **Fig. 2** Relationship between s-RPE TL and Summated HR Zone TL for field hockey (r = 0.6).

heart rate in keeping with the sHRz method [14]. Time spent in each of the heart rate zones was multiplied by a factor relevant to each zone (50–59 % x 1, 60–69 % x 2, 70–79 % x 3, 80–89 % x 4 and 90–100 % x 5) with the results summated to provide a measure of internal training load in arbitrary units.

## Statistical analyses
Within-participant correlations and associated 95 % confidence intervals (95 % CI) were calculated between s-RPE and the sHRz method [5]. In previous research [2, 20, 25], the correlation between the two methods has been calculated mainly by pooling data over time points, or by calculating Pearson's correlation coefficients separately for individual participants. Such approaches lead to a lower level of statistical precision and/or the problem of "pseudoreplication" in data analysis [27]. The magnitude of the correlation was labelled according to the following thresholds; r = 0.1–0.29 = small, 0.3–0.49 = moderate, 0.5–0.69 = large, 0.7–0.89 = very large, 0.9–0.99 = nearly perfect, 1 = perfect [24]. Differences between the independent correlation coefficients for each sport were assessed by converting each correlation coefficient into a z score using Fisher's r-to-z transformation [9]. Statistical analyses were carried out using the SPSS statistical analysis software for Mac (version 24.0, SPSS Inc., Chicago, IL, USA).

## Results
When all sports were considered together, changes in s-RPE were largely correlated to changes in the sHRz score (r = 0.67; 95 % CI 0.61–0.72). When the within-participant correlations were considered independently for each sport, correlations remained large for rugby (r = 0.68; 95 % CI 0.59–0.75) (► **Fig. 1**) and field hockey (r = 0.60; 95 % CI 0.47–0.71) (► **Fig. 2**), and very large for soccer (r = 0.72; 95 % CI 0.62–0.80) (► **Fig. 3**), although these confidence limits overlapped and there were no statistically significant differences between rugby & field hockey (p = 0.27; 95 % CI −0.10 ≤ 0.08 ≤ 0.38), soccer & rugby (p = 0.52; 95 % CI
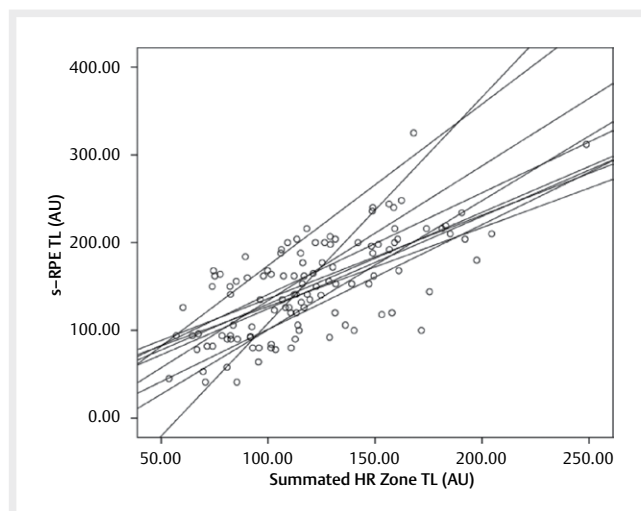


► **Fig. 3** Relationship between s-RPE TL and Summated HR Zone TL for football (r = 0.72).

−0.16 ≤ 0.04 ≤ 0.32) and soccer & field hockey (p = 0.11; 95 % CI −0.05 ≤ 0.12 ≤ 0.48). The root mean square error calculated from the standard deviation of the model residuals was approximately 35 s-RPE arbitrary units.

## Discussion
The purpose of the current study was to quantify the correlation between s–RPE and the sHRz method of quantifying internal training load in youth athletes, whilst also assessing the influence of sport on the magnitude of the correlation. Analyses demonstrated a large correlation when all athletes were considered together, whilst within-participant correlations for individual sports showed large correlations for rugby and field hockey and a very large correlation for soccer. Therefore, coaches and schoolteachers alike can

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confidently use s-RPE as a measure of internal training load in youth athletes of these sports.

The findings of this study demonstrating the large and very large correlations between s-RPE and sHRz are lower than the mean magnitude of correlation found in tennis (r = 0.74) [20], swimming (r = 0.75) [37], and female soccer (r = 0.85) [2]. However, the magnitude of correlation found within youth soccer in the present study is comparable to the range found in a similar cohort (r = 0.54 to 0.78) [25]. The lack of research within youth sport makes it difficult to conclusively identify an explanation for the smaller correlations found in the present study. One potential explanation is the age and experience of the cohorts investigated. Both age [22] and experience [21] have been suggested to influence RPE response, and the cohorts investigated in tennis (18.5 ± 0.4), swimming (22.3 ± 3.1), and female soccer (19.3 ± 2) were all older than the cohort investigated in this study (16.7 ± 0.8).

Previous attempts to assess the association between the s-RPE and sHRz methods of monitoring internal training load have predominantly utilised a restricted method of statistical analysis. Pooling the data fails to consider case independence and is associated with exaggerated degrees of freedom, whereas calculating the mean of the range of individual correlations compromises statistical power [3]. The present study controls for subjects as a factor, subsequently providing a more precise assessment. To the authors' knowledge, only one other study has assessed the relationship between s-RPE and sHRz using within-participant correlations that found a magnitude of correlation (r = 0.75; 95 % CI 0.71–0.78) in senior male soccer [27] similar to that of the youth soccer players investigated in this study. This would suggest that the association between s-RPE and heart rate remains consistent from youth- to senior-level soccer.

Although heart rate-derived training loads have been shown to be suitable in quantifying internal load during endurance training [17], they may not be as valid during high-intensity intermittent exercise due to the influence of muscular acidosis [2]. Previous research has demonstrated a combination of blood lactate and heart rate measures were better related to RPE in comparison to blood lactate and heart rate measures alone [10]. Rugby [30], soccer [4] and field hockey [35] are all team sports characterised by low-intensity locomotion interspersed with bouts of high-intensity activity. Such high-intensity activities may have led to increases in participant's blood lactate concentration increasing perceptions of exertion and restricting the magnitude of correlation between s-RPE and sHRz. Additionally, heart rate time-in-zone methods tend to underestimate session intensity during recovery [32]. Following an intense period of training, heart rate will return to a lower zone, increasing the time spent at lower intensity when summating the heart rate score, failing to depict the accumulated metabolic distress and likely misrepresenting the perceived effort and blood lactate profile of the session. Therefore, s-RPE may encapsulate factors influencing effort which are not represented by heart rate, restricting the correlation between the two methods of internal load quantification.

Conversely, s-RPE may underestimate load during short but intense training sessions when ratings of exertion are multiplied by session duration. Previous research [33] has demonstrated 4 × 4-minute bouts of intermittent exercise to produce the greatest heart rate, lactate and RPE responses in comparison to 4 × 8-minute and 2 × 16-minute bouts of matched exercise. Despite this, when ratings of intensity were multiplied by duration, the 4 × 4-minute condition yielded the lowest s-RPE load. Therefore, although s-RPE appears to offer an accurate measure of internal training load, some precautions must be taken particularly during the quantification of short and intense training.

A secondary aim of the present study was to assess the influence of sport on the magnitude of correlation, with Fisher's r-to-z transformation revealing no significant differences between the correlations for each sport. Adolescent rugby union is characterised by frequent bouts of physical contact [30]. The physical contact associated with rugby union play can lead to subsequent muscle damage [31], whilst research in rugby league has demonstrated increased perceptions of effort together with increases in physical contact [26]. Due to the fatigue induced through physical contact, potentially not represented by a linear increase in heart rate, it may have been expected that the magnitude of correlation between s-RPE and the sHRz method was reduced for youth rugby in comparison to soccer and field hockey. A potential reason for the lack of difference in correlation between rugby, soccer and field hockey is that perceptions of effort and heart rate were quantified only during training sessions. Due to the fatigue induced through physical contact, it may be that bouts of physical contact were actively reduced by the coaches during training sessions to maintain player freshness prior to match day. Further research should seek to investigate the relationship between s-RPE and the sHRz method of quantifying internal training load between different sports during match play when the characteristics of each sport are accurately represented.

## Conclusion

The accurate quantification of internal training load is essential to facilitate the assessment of how the athlete is responding to the prescribed training load, potentially reducing the negative implications associated with over- and undertraining. Heart rate monitoring has long been established as a popular method of quantifying internal exercise intensity [1]. Despite this, the potential for incomplete heart rate traces and subsequent missing data alongside the time and cost associated with this method means that it may not be the most efficient method of quantifying internal training load. The s-RPE method offers a practical and cost-efficient solution, with the present study highlighting the validity of s-RPE in comparison to the sHRz method. Very large and large correlations were found for youth soccer, rugby and field hockey, respectively, meaning coaches and practitioners can confidently utilise the s-RPE method for quantifying internal load in these sports.

## Conflict of Interest

The authors declare that they have no conflict of interest.

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## References

[1] Achten J, Jeukendrup AE. Heart rate monitoring: applications and limitations. Sport Med 2003; 33: 517–538

[2] Alexiou H, Coutts AJ. A comparison of methods used for quantifying internal training load in women soccer players. Int J Sports Physiol Perform 2008; 3: 320–330

[3] Atkinson G, Batterham AM, Jones H, Taylor CE, Willie CK, Tzeng YC. Appropriate within-subject statistical models for the analysis of baroreflex sensitivity. Clin Physiol Funct Imaging 2011; 31: 80–82

[4] Billows D, Reilly T, George K. Physiological demands of match play and training in elite adolescent footballers. In: Reilly T, Cabri J, Araújo D.eds. Science and Football V.. London and New York: Routledge; 2005: 469–477

[5] Bland JM, Altman DG. Calculating correlation coefficients with repeated observations: Part 1–Correlation within subjects. BMJ 1995; 310: 446

[6] Borresen J, Lambert M. Quantifying training load: A comparison of subjective and objective methods. Int J Sports Physiol Perform 2008; 3: 16–30

[7] Buchheit M. The 30-15 Intermittent Fitness Test: A new intermittent running field test for intermittent sport players-Part 1. Approch du Handball 2005; 87: 27–34

[8] Casamichana D, Castellano J, Calleja-Gonzalez J, San Roman J, Castagna C. Relationship between indicators of training load in soccer players. J Strength Cond Res 2013; 27: 369–374

[9] Cohen J, Cohen P, West SG, Aiken Leona S. Applied multple regression/correlation analysis for the behavioural sciences. Routledge; 2013

[10] Coutts AJ, Rampinini E, Marcora SM, Castagna C, Impellizzeri FM. Physiological correlates of perceived exertion during soccer-specific exercise. J Sci Med Sport 2009; 12: 79–84

[11] Cuff S, Loud K, O'Riordan MA. Overuse injuries in high school athletes. Clin Pediatr (Phila) 2010; 49: 731–736

[12] Day M, Mcguigan M, Brice G, Foster C. Monitoring exercise intensity during resistance training using the session RPE scale. J Strength Cond Res 2004; 18: 353–358

[13] Difiori JP, Benjamin HJ, Brenner J, Gregory A, Jayanthi N, Landry GL, Luke A. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. Clin J Sport Med 2014; 24: 3–20

[14] Edwards S. The heart rate monitor book. Med Sci Sport Exerc 1994; 26: 647

[15] Emery Ca, Meeuwisse WH, Hartmann SE. Evaluation of risk factors for injury in adolescent soccer: implementation and validation of an injury surveillance system. Am J Sports Med 2005; 33: 1882–1891

[16] Fanchini M, Ghielmetti R, Coutts AJ, Schena F, Impellizzeri FM. Effect of training-session intensity distribution on session rating of perceived exertion in soccer players. Int J Sports Physiol Perform 2015; 10: 426–430

[17] Foster C. Monitoring training in athletes with reference to overtraining syndrome. Med Sci Sport Exerc 1998; 30: 1164–1168

[18] Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, Doleshal P, Dodge C. A new approach to monitoring exercise training. J Strength Cond Res 2001; 15: 109–115

[19] Gallo T, Cormack S, Gabbett T, Williams M, Lorenzen C. Characteristics impacting on session rating of perceived exertion training load in Australian footballers. J Sports Sci 2014; 33: 1–9

[20] Gomes RV, Moreira A, Lodo L, Capitani CD, Aoki MS, Foster C, Jenkins D. Ecological validity of session RPE method for quantifying internal training load in tennis. Int J Sports Sci Coach 2015; 10: 729–737

[21] Groslambert A, Mahon AD. Perceived exertion : influence of age and cognitive development. Sports Med 2006; 36: 911–928

[22] Haddad M, Padulo J, Chamari K. The usefulness of session rating of perceived exertion for monitoring training load despite several influences on perceived exertion. Int J Sports Physiol Perform 2014; 9: 882–883

[23] Halson SL. Monitoring training load to understand fatigue in athletes. Sport Med 2014; 44: 139–147

[24] Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 2009; 41: 3–12

[25] Impellizeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. Med Sci Sport Exerc 2004; 36: 1042–1047

[26] Johnston RD, Gabbett TJ, Seibold AJ, Jenkins DG. Influence of physical contact on neuromuscular fatigue and markers of muscle damage following small-sided games. J Sci Med Sport 2014; 17: 535–540

[27] Kelly DM, Strudwick AJ, Atkinson G, Drust B, Gregson W. The within-participant correlation between perception of effort and heart rate-based estimations of training load in elite soccer players. J Sports Sci 2016; 34: 1–5

[28] Matos NF, Winsley RJ, Williams CA. Prevalence of nonfunctional overreaching/overtraining in young English athletes. Med Sci Sports Exerc 2011; 43: 1287–1294

[29] Phibbs P, Jones B, Roe G, Read D, Darrall-Jones J, Weakley J, Till K. We know they train, but what do they do? Implications for coaches working with adolescent rugby union players. Int J Sport Sci Coach 2016; 12:175–182

[30] Read D, Jones B, Phibbs P, Roe G, Darrall-Jones J, Weakley J, Till K. Physical demands of representative match play in adolescent rugby union. J Strength Cond Res 2016; 35:1290–1296

[31] Roe G, Till K, Phibbs P, Weakley J, Read D, Jones B. Changes in markers of fatigue following a competitive match in elite academy rugby union players. South African J Sport Med 2016; 28: 3–6

[32] Seiler S. What is best practice for training intensity and duration distribution in endurance athletes? Int J Sport Physiol Perform 2010; 5: 276–291

[33] Seiler S, Jøranson K, Olesen BV, Hetlelid KJ. Adaptations to aerobic interval training: interactive effects of exercise intensity and total work duration. Scand J Med Sci Sport 2013; 23: 74–83

[34] Stewart AM, Hopkins WG. Seasonal training and performance of competitive swimmers. J Sports Sci 2000; 18: 873–884

[35] Sunderland C, Edwards PL. Activity profile and between-match variation in elite male field hockey. J Strength Cond Res 2017; 31: 758–764

[36] Valovich McLeod TC, Decoster LC, Loud KJ, Micheli LJ, Parker JT, Sandrey MA, White C. National Athletic Trainers' Association position statement: prevention of pediatric overuse injuries. J Athl Train 2011; 46: 206–220

[37] Wallace LK, Slattery KM, Coutts AJ. The ecological validity and application of the session-RPE method for quantifying training loads in swimming. J Strength Cond Res 2009; 23: 33–38

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