Differential ratings of perceived match and training exertion in youth female soccer

Original investigation

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Abstract

Purpose: To understand the validity of differential ratings of perceived exertion (dRPE) as measure of girl's training and match internal loads.

Methods: Using the centiMax scale (CR100®), session dRPE for breathlessness (sRPE-B) and leg muscle exertion (sRPE-L) were collected across a season of training (soccer, resistance, fitness) and matches from 33 players (15 ± 1 years). Differences and associations between dRPE were examined using mixed and general linear models. Our minimal practical important difference was 8 arbitrary units [AU].

Results: Mean (AU ± standard deviation ~16) sRPE-B and sRPE-L were 66 and 61 for matches, 51 and 49 for soccer, 86 and 67 for fitness, and, 45 and 58 for resistance. Session RPE-B was rated most likely harder than sRPE-L for fitness (19 AU; 90% confidence limits [CL]: ±7) and most likely easier for resistance (-13; ±2). Match (5; ±4) and soccer (-3; ±2) differences were likely to most likely trivial. The within-player relationships between sRPE-B and sRPE-L were very likely moderate for matches (r = 0.44; 90% CL: ±0.12) and resistance training (0.38; ±0.06), likely large for fitness training (0.51; ±0.22) and most likely large for soccer training (0.56; ±0.03). Shared variance ranged from 14-35%.

Conclusions: Practically meaningful differences between dRPE following physical training sessions coupled with low shared variance in all training types and matches suggest that sRPE-B and sRPE-L represents unique sensory inputs in girls soccer players. Our data provide evidence for the face and construct validity of dRPE as measures of internal load in this population.

Introduction

The English Football Association support girls soccer Regional Talent Clubs (RTC) to develop elite players. There is an abundance of research on the physical aspects of male soccer (e.g., match analysis, fitness characteristics, and training patterns) but as yet research on the female game is largely confined to match analysis of elite senior competition and fitness characteristics. The demands of RTC soccer have not been previously captured, making it difficult for practitioners to adequately plan effective training to prepare players for the physical demands of matches. Using data from elite women[1] to inform the training of developmental players is not ideal given, for example, differences in maturity and fitness [2].

Understanding the internal response to external loads placed upon players is particularly relevant to practitioners. [3,4] Internal response to training can be measured practically using session ratings of perceived exertion (sRPE), which provide a valid quantification of relative exercise intensity and internal load across a range of exercise modalities. [5,6] Ratings of perceived exertion are also cost- and time-effective, lending to girls RTC programmes where resources can be limited. However, sRPE, as a gestalt measure of internal load, may not adequately appraise the entire range of exercise-induced perceptual sensations, thereby lacking sensitivity.[7] Differentiating between central and peripheral inputs may be one solution to overcome this issue and, provide a broader understanding of internal training load. [7,8]

An emerging body of evidence is available to suggest that differential RPE (dRPE) are a worthwhile addition to internal monitoring procedures in team sports, as athletes often perceive a substantial difference between their central (i.e. breathlessness; sRPE-B) and peripheral (i.e. leg muscle; sRPE-L) exertion when this difference is theoretically known or expected (face and construct validity). [9] For these reasons, dRPE have been recommended as a suitable indirect alternative to measuring an athlete's internal physiological (i.e. cardiovascular) and biomechanical (i.e. neuromuscular) internal loads.[10] This could be useful to those responsible for the physical development of female youth soccer players, as physiological and biomechanical systems differ in rates of adaptation, recovery and growth/development. [10,11]

In response to experimental evidence demonstrating no difference between dRPE (from one another and from global sRPE; [12-15]), some authors have questioned the value in this method. [14,16] Furthermore, it has been suggested that dRPE and global sRPE are not mutually exclusive constructs, [16] meaning that a change in one dimension will be met proportionately by all others. This has implications for athlete monitoring, because it would be inefficient to collect several highly correlated measures of training load explaining the same information.[17] As such, there is a need for further research to understand if dRPE provides added value in the measurement of internal load over sRPE alone. For example, do dRPE provide different information not only to one another but also when compared to sRPE? Moreover, no research has yet evaluated dRPE in youth, where research on adult populations may not be transferable given the potential for cognitive development to influence the accuracy of RPE. [18]

Our retrospective study was therefore designed with an overarching aim of providing a comprehensive understanding of dRPE and its validity in girls RTC soccer. Subsequently, the objectives were to: 1) quantify differences in ratings (global and differential) following training and match-play as a means of assessing validity via known groups differences, and 2) provide the first examination of the within-player associations between each dRPE and global sRPE for matches, soccer and, resistance training.

Methods

Participants

Thirty-three girls' soccer players (age 15 ± 1 years, stature 163 ± 7 cm, body mass 55 ± 9 kg, maturity offset 1.8 ± 1.1 years from peak height velocity) representing an FA Regional Talent Club, participated in this retrospective observational research. Maturation, expressed as years from peak-height velocity was estimated using the players' mass, sitting and standing stature with chronological age. [19] Players typically attended two 90-minute soccer and one 70-minute resistance training session each week. Resistance training involved a variety of neuromuscular training stimuli as outlined previously. [20] Occasionally, typical training sessions were replaced throughout the season with conditioning sessions targeting the development of aerobic fitness. These sessions typologies were classified for analysis by their primary or targeted goal ('soccer', 'resistance', 'fitness'). Players also completed one 60 minute "movement" training session which combined technical and fundamental movement skills aiming to provide broad and varied cognitive and technical stimuli. As such, we did not feel it was conceptually relevant to differentiate between perceptual stimuli here and these "movement" sessions were not included.

Ethics approval was granted from the University ethics committee (SSSBLREC008) and conducted to standards set out in the Declaration of Helsinki. After obtaining player and parental consent, RPE were collected for each training session and, nine soccer matches over the course of a season. We collected 1097 observations for soccer training (n=50 training sessions), 558 for strength and conditioning (n=33) and 64 for fitness training (n = 3). In total, 157 match observations (n=10) were made throughout the season. On each observation all three RPE were collected in the same order (global RPE, sRPE-B, sRPE-L) and at the same time.

Methodology

Approximately 15–30 minutes post-session, players used a touch-screen tablet application[21] (Iconia One 7 B1-750, Taipei, Taiwan: Acer Inc.) to record their sRPE (global, sRPE-B, sRPE-L) via the CR100® scale, which was numerically blinded, labelled with the idiomatic English verbal anchors. This allowed each player to record their scores confidentially to mitigate issues of conformation and cognitive bias (i.e., ratings influenced by team mates). Players were habituated with this procedure for approximately 1 year prior to the current study, ensuring familiarity with the entire range of sensations that correspond to each category of effort within the CR100® scale (i.e. 'anchoring'). Players received prior instruction on the definition of effort perception, including its separation from other exercise related sensations such as fatigue, pain or discomfort, and how to appraise feelings of overall effort, breathlessness, leg muscle exertion and technical/cognitive demands.

Statistical Analysis

We inspected the histograms and Q-Q plots of the raw data visually for normal distribution. All data were approximately normal with the exception of sRPE-B where a slight positive skew was observed for fitness. Mixed linear modelling (SPSS Statistics version 24) was used to analyse the difference between fixed effects (comparing between sRPE types within a training modality or match, and comparing training sRPE with match sRPE [reference category]), while using a random effect for player (intercept; variance components) to account for repeated within-athlete observations (subsequently expressed as standard deviations [SD]). To determine if higher global sRPE were associated with dRPE, a general linear model was used to provide estimates of within-player correlations. [8,22]

Uncertainty in all estimates were expressed as 90% confidence intervals (CI). We subsequently applied non-clinical magnitude-based decisions [23,24] to describe the size and precision of sRPE differences and correlations. Here, the disposition of the effect distribution (t for sRPE differences and z for sRPE correlations) in relation to thresholds for substantiality were evaluated as probabilities (percent chances). For sRPE differences, we used a minimum practically important difference of 8 AU, as this magnitude represents the shift required for a player's rating to be typically closer or equal (e.g. halfway) to the next or preceding effort category on the non-linear CR100® scale [9]. This is more conservative compared to choosing a distribution-based approach (e.g., 0.2 × between-player SD), which are often far lower than 7–10 AU. [9] We acknowledge that this threshold is not perfect, particularly as the non-linearity of category-ratio scales presents a challenge to setting such a threshold however, we feel this represents a step-forward in attempting to define a practical important difference. Standardised effect sizes were calculated from the pooled within- and between-subject SD and reported but not interpreted not only because they may lack practical context but also as they maybe more vulnerable to sample variance. [25] For within-player correlations, and in light of no practical anchor for a meaningful association, thresholds of 0.10, 0.30, 0.50, and 0.70 were used to anchor small, moderate, large and very large relationships, respectively. [23] Given the above concerns regarding standardization the raw effect slopes were calculated and presented additionally.

Probabilities of effects being greater than these thresholds were qualified as: 0.5–5.0 % very unlikely; 5.0–24.9 % unlikely; 25.0–74.9 % possibly; 75.0–94.9 % likely; 95.0–99.5 % very likely; > 99.5 % most likely. Finally, given the chance of inflated type I error with multiple comparisons, all inferences were re-evaluated with 99% CI. [23]

Results

Mean global and differential sRPE for each typology are presented with between- and within-player SDs in Figure 1. On average, matches were rated hard to very hard for both breathlessness and leg muscle exertion; soccer training was rated hard for breathlessness and leg muscle exertion; fitness training was rated very to extremely hard for breathlessness and hard to very hard for leg muscle exertion, and; resistance training was rated somewhat hard to hard for breathlessness and hard to very lard for leg muscle exertion.

We present differences in exertion between typologies in Table 1. Session RPE-B was most likely harder than sRPE-L for fitness and most likely easier for resistance. Match and soccer dRPE differences were likely to most likely trivial.

The differences between RPEs, within typologies, are presented in Table 2. Compared to matches: soccer training was rated substantially easier for all exertion types; resistance training was substantially easier for global sRPE and sRPE-B, but not sRPE-L, and; fitness training was rated substantially harder for all exertion types.

Within- player correlations between exertion types are presented in Figure 2 and Figure 3. The within-player relationships between sRPE-B and sRPE-L were very likely moderate for matches (r^2 = 0.19) and resistance training (r^2 = 0.14), likely large for fitness (r^2 = 0.26) training and most likely large for soccer training (r^2 = 0.31).

Discussion

We present for the first-time data describing the internal training and match exertion in girls RTC soccer. Through examination of post-match and training ratings (global and differential) we observed practically meaningful differences between sRPE-B and sRPE-L following training with distinct physical outcomes (e.g., fitness and resistance). These differences may reflect the different physiological stresses of fitness and resistance training, providing further evidence of face and construct validity of dRPE via known groups differences.[26] Conversely, we also observed moderate to large within-player associations between differential and global sRPE (range in within-player *r* of 0.38–0.67). While this supports previous theories that differentiated ratings are not mutually exclusive constructs, [16] it also implies that the shared variance between ratings is low (14–45%). Collectively, these findings suggest that dRPE represent unique sensory inputs, providing evidence for face and construct validity as measures of internal response in girls soccer players.

Practically meaningful differences between sRPE-B and sRPE-L were observed in training typologies with a distinct physical goal (i.e. fitness and resistance), yet differences in perception of breathlessness and leg exertion observed in soccer training, where the goal was primarily technical and/or tactical were, trivial. This trivial difference could be explained by the fact that although soccer training was not prescribed with a targeted physical stimulus, the central and peripheral internal responses associated with the session are nonetheless substantial (Figure 1, 'Hard') and likely to vary on a session-to-session basis (ranging from more central to more peripheral) across long operational periods. For resistance training, however, global sRPE and sRPE-L were rated substantially harder than sRPE-B (Table 2), likely reflective of the musculoskeletal and neurological aspect of this training typology. Given the goal of resistance training is to stress the neurological and musculoskeletal systems by exerting force against a resistance to elicit acute (neuroendocrine) and chronic (neurological or morphological) adaptations, [27,28] it seems logical that players would perceive higher sRPE-L when compared with sRPE-B. For fitness sessions, sRPE-B was rated substantially harder than leg exertion. These training sessions were running based interval training and targeted improvements in soccer specific aerobic fitness. [29] Whilst, we were limited to 64 observations on only three training sessions higher sRPE-B has been shown for similar training sessions previously [21] and may reflect the central or cardiovascular demands [30] of this training modality. [31] Indeed, higher cumulative sRPE-B has been associated with improvements in Yo-Yo intermittent recovery test level 1 performance in team sport athletes. [9] Collectively, these sRPE-B and sRPE-L differences provide evidence to support the validity of dRPE in youth female soccer players.

In matches sRPE-B was harder than sRPE-L by 5 AU (90% CI ~1 to 9, effect size 0.34,) but we did not regard this difference to be practical meaningful (> 8 AU, Table 2). There was also a trivial difference between match sRPE-B and global sRPE, yet match sRPE-L was substantially lower than global sRPE. This could suggest that the global effort sense is mediated more so by central as opposed to peripheral factors in youth female soccer players during matches. Indeed, match sRPE-B had the strongest within-player association with global sRPE, which would further support such a statement. Previously, peripheral sensations have been rated higher than central in match play in elite male Australian Rules Football players [8] and semi-professional male soccer players [13]. The disparity in these findings with our current data could represent differences in aerobic and anaerobic capability between adults and adolescents, [11] with the latter typically lower due to development, growth and maturation. Adolescent girls may also be more efficient in re-synthesis of phosphocreatine than women. [32] In contrast, previous literature suggests perceptions of leg exertion appear to provide the dominant sensory signal in younger children (8 – 12 years), but this maybe explained by the choice of cycle ergometery as a modality in these studies. [18] Overall, this could indicate that central or aerobic fitness is an important physical quality associated with the response to match-play in this population.

Despite dRPE appearing sensitive in the ability to capture discrete sensory inputs, separate ratings for central and peripheral perceived exertion may not be entirely mutually exclusive constructs [16] and our data are in support of this. We report for the first time moderate to large within-player correlations between dRPE (range in *r*: 0.59–0.69) and of global sRPE with both sRPE-B (0.59–0.69) and sRPE-L (0.34–0.51; Figure 2). Practically, this implies that during girls soccer training and match-play, a change in one sRPE dimension (overall, central or peripheral) is strongly associated with a change in any other. Despite this, our largest observed correlation, between global and breathlessness RPE in soccer training, was 0.67, which at best explains only 45% of the variance between the two measures. Furthermore, despite no practically meaningful differences between sRPE-B and sRPE-L following match-play or soccer training, the shared variance between the two measures was 19–31%. Thus, despite some clear collinearity between global, central, and peripheral perceived exertion, we feel that these data do in fact strengthen the case for adopting dRPE to monitoring strategies in girls soccer.

Data collected from players during training and matches can aid athlete management, training prescription and decision making—ultimately facilitating player development. In our investigation, sRPE-B was substantially higher for fitness training compared to matches. Soccer specific fitness has been observed previously to improve over pre-season in response to fitness training in these players but not the in-season period where players perform predominantly soccer and resistance training [29,33] Together, these data suggest the use of targeted fitness training interventions that increase sRPE-B (such as high-intensity interval training [29]) over the in-season period could be justified particularly given the substantial sex differences reported between boys and girls players. [2] Practitioners may wish to design such interventions so as to sensibly expose players to exertion that is beyond match intensity as opposed to training that purely replicates competition. However, given the low number of observations for fitness in our study we would recommend further research here.

We observed substantial within- and between- player variation in all sRPE types for all training typologies (Figure 1). For match intensity, within-player (match-to match) variability was similar to that reported in elite male AFL players,[8] but our between-player variability (heterogeneity) was larger. It is likely the range in maturation and training status of our youth players explains the greater between-player variation compared with professional athletes. Cardiorespiratory factors involved in RPE appear to increase with aging and, adolescence corresponds with an increase in logical-mathematic meaning. [18] Whilst there is a relative paucity of conclusive research in this area it is possible that differences in both physical and cognitive maturation could partly explain this heterogeneity. This highlights the importance of comparing within- rather than between players when monitoring training in girls' soccer. Coaches and practitioners should thus be aware of the uncertainty in these data when assessing practically important changes in an individual player's sRPE.

The common use of standardised effect sizes in sports performance research has recently been challenged (e.g. Kyprianou and colleagues [25]), with anchors of practical importance recommended as preferable to interpret the magnitude of an effect. [34] We elected to use a minimum practically important difference of 8 AU, as this magnitude represents a typical 'on the scale' change required for a player's RPE to be closer or equal (e.g. halfway) to the next or preceding effort category across the non-linear CR100® scale. [9] We acknowledge that this threshold is not perfect, but had we used the more common approach of standardization (e.g., 0.2 SDs; ~3 AU in this instance) we would have interpreted substantial differences between ratings that lack practical relevance (e.g., 5 of the 7 trivial inferences in Table 1 would have appeared substantial). For example, match RPE-B would have appeared likely harder than match RPE-L (81% chance), constituting a small standardised effect size (0.34, ± 0.26). The interpretation of correlations using standardised thresholds (r and r^2) could be similarly criticised. For example, despite moderate to large correlations, changes in global sRPE between matches of >22 ±8 AU or >13 ±3 AU would be required to be equivalent to a practically meaningful change in sRPE-L or sRPE-B respectively. A potential additional advantage of reporting the non-standardised slopes (figures 3 and 4) is that it allows interpretation of these relationships in raw units that may be more relatable for coaches and practitioners. We therefore recommend consideration of a minimum practically important difference (e.g., 8 AU) [9] for those interpreting RPE in both research and practice.

The main limitation to our study was the observational, rather than experimental, nature of the research design, which may limit the level of evidence and overall conclusions drawn from the data. Furthermore, while our aims were to further understand dRPE in a girls soccer population, our findings may be limited to this group and it is as yet unknown if the findings drawn from our sample (one RTC) are reflective of the wider population. We were also unable to quantify external load within this study which may limit our understanding of the specific types of activity that result in a given internal response (for example, we do not know if a higher sRPE in a match is due to greater total distance covered or the requirement to repeat more bouts of high-speed running). However, this provides a notable first step to understanding the demands of RTC soccer and further research with multiple RTCs would be warranted.

Practical applications.

There may be several practical applications from both training monitoring and physical preparation perspectives that can be drawn from our current findings. Assessing the differences between global and differential sRPE may provide practitioners with useful information into the specific internal responses following training and matches in youth female soccer players. More specifically, since there appears to be a moderate to large association between global, central and peripheral exertion, substantial deviations from the linear relationship between any two of these constructs can be used to infer on 'unusual' changes that could be caused by fitness or fatigue. [4] Regarding the interpretation of an individuals' data, we estimate that a threshold of 8–19 AU represents possible to likely meaningful changes in match or training sRPE. This was derived following methods previously described,[8] using our within-player SD of 15–16 AU, a threshold for minimum practical importance of 8 AU, an 80% confidence level. We acknowledge that 19 AU is both a large and conservative threshold, but practitioners can be confident that changes of this magnitude are likely free from noise and also of real-world importance. Practically, changes of this magnitude might simply represent a typically 'hard' session being subsequently rated as 'somewhat hard' or 'very hard'. Alternatively, in athlete monitoring it may be more problematic to make a type II rather than a type I error, a threshold of 8 AU is possibly real e.g. harder (50% chance) but, practitioners should be aware of the possibility that it could be either trivial (34% chance), or indeed easier (16% chance). Finally, from a physical preparation perspective, our data show that soccer training alone may not provide an adequate stimulus to prepare players for the internal demands of matches. Incorporating aerobic conditioning to target sRPE-B above match intensity and, neuromuscular training for sRPE-L into girls' RTC training could be beneficial to prepare players for the demands of the game. [20]

Conclusions

In the first investigation of girls soccer match and training dRPE, we found practically meaningful differences between global, central and peripheral ratings collected in youth female soccer players following training sessions which target physical outcomes. When the direction and magnitude of these differences are aligned with the known physiological and biomechanical responses to exercise, our data provide evidence for the face and construct validity of dRPE in girls soccer players. With the putative practical recommendations in mind, our data suggest that dRPE are valid and a worthwhile addition to training and match monitoring for RTC practitioners.

Figure legends:

Figure 1: Mean global and dRPE for matches and training typologies with error bars represented the between- (thin black lines) and within- (thick grey lines) player standard deviations.

Figure 2: Within-player correlations for sRPE-B and sRPE-L with global RPE. Standardised (r) and raw (β) effects are presented with the uncertainty expressed as ±90% confidence limits.

Figure 3: Within-player correlations for sRPE-L with sRPE-B with global RPE. Standardised effect sizes are presented (r) with the uncertainty expressed as ±90% confidence limits

References

1. Datson N, Drust B, Weston M, Gregson W. Repeated high-speed running in elite female soccer players during international competition. *Sci Med Football*. 2018;00(00):1-7. doi:10.1080/24733938.2018.1508880.

2. Mujika I, Santisteban J, Impellizzeri FM, Castagna C. Fitness determinants of success in men's and women's football. *J Sports Sci*. 2009;27(2):107-114. doi:10.1080/02640410802428071

3. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and external training load: 15 years on. *Int J Sports Physiol. Perform*. 2019;14(2):270-273. doi:10.1123/ijspp.2018-0935.

4. Mclaren SJ, Macpherson TW, Coutts AJ, Hurst C, Spears IR, Weston M. The relationships between internal and external measures of training load and intensity in team sports: a meta-analysis. *Sports Med*. 2017;48(3):641-658. doi:10.1007/s40279-017-0830-z.

5. Chen MJ, Fan X, Moe ST. Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *J Sports Sci*. 2010;20(11):873-899. doi:10.1080/026404102320761787.

6. Scantlebury S, Till K, Atkinson G, Sawczuk T, Jones B. The within-participant correlation between s-RPE and heart rate in youth sport. *Sports Med Int Open*. 2017;1(06):E195-E199. doi:10.1055/s-0043-118650.

7. Weston M. Difficulties in Determining the Dose-response nature of competitive soccer matches. *J Athletic Enhancement*. 2013;02(01):1-5. doi:10.4172/2324-9080.1000e107.

8. Weston M, Siegler J, Bahnert A, McBrien J, Lovell R. The application of differential ratings of perceived exertion to Australian Football League matches. *J Sci. Med Sport*. 2015;18(6):704-708. doi:10.1016/j.jsams.2014.09.001.

9. Mclaren SJ. The application of differential ratings of perceived exertion to training monitoring in team sports (Doctoral Thesis).

10. Vanrenterghem J, Nedergaard NJ, Robinson MA, Drust B. Training Load Monitoring in Team Sports: A Novel Framework Separating Physiological and Biomechanical Load-Adaptation Pathways. *Sports Medicine*. 2017;47(11):2135-2142. doi:10.1007/s40279-017-0714-2.

11. Boisseau N, Delamarche P. Metabolic and Hormonal Responses to Exercise in Children and Adolescents. *Sports Med*. 2000;30(6):405-422. doi:10.2165/00007256-200030060-00003.

12. Leceaga J, Los Arcos A, Castillo Alvira D, Yanci J. Influence of plyometric training volume on differentiated perceived exertion load of high level soccer players. *PensarMov*. 2017;15(2):27664–17. doi:10.15517/pensarmov.v15i2.27664.

13. Los Arcos A, Yanci J, Mendiguchia J, Gorostiaga EM. Rating of muscular and respiratory perceived exertion in professional soccer players. *J Strength Cond Res.* 2014;28(11):3280-3288. doi:10.1519/JSC.0000000000000540.

14. Los Arcos A, Mendez-Villanueva A, Yanci J, Martínez-Santos R. Respiratory and muscular perceived exertion during official games in professional soccer players. *Int J Sports Physiol Perform*. 2016;11(3):301-304. doi:10.1123/ijspp.2015-0270.

15. Azcárate U, Yanci J, Arcos AL. Influence of match playing time and the length of the between-match microcycle in Spanish professional soccer players' perceived training load. *Sci Med Football.* 2018;2(1):23-28. doi:10.1080/24733938.2017.1386322.

16. Green JM, McIntosh JR, Hornsby J, Timme L, Gover L, Mayes JL. Effect of exercise duration on session RPE at an individualized constant workload. *Eur J Appl Physiol*. 2009;107(5):501-507. doi:10.1007/s00421-009-1153-z.

17. Weaving D, Jones B, Marshall P, Till K, Abt G. Multiple measures are needed to quantify training Lloads in professional rugby league. *Int J Sports Med*. 2017;38(10):735-740. doi:10.1055/s-0043-114007.

18. Groslambert A, Mahon AD. Perceived exertion. *Sports Med*. 2006;36(11):911-928. doi:10.2165/00007256-200636110-00001.

19. Mirwald RL, Baxter-Jones ADG, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. *Med Sci Sports Exerc*. 2002;34(4):689-694.

20. Wright MD, Laas M-M. Strength training and metabolic conditioning for female youth and adolescent soccer players. *Strength Cond J.* 2016;38(2):96-104. doi:10.1519/SSC.0000000000000212.

21. Mclaren SJ, Smith A, Spears IR, Weston M. A detailed quantification of differential ratings of perceived exertion during team-sport training. *J Sci Med Sport*. 2017;20(3):290-295. doi:10.1016/j.jsams.2016.06.011.

22. Bland JM, Altman DG. Statistics notes: Calculating correlation coefficients with repeated observations: Part 1—correlation within subjects. *Br Med J.* 1995;310(6977):446-446. doi:10.1136/bmj.310.6977.446.

23. Hopkins WG. A Spreadsheet for deriving a confidence interval, mechanistic inference and clinical inference from a p value. *Sportscience*. 2007;11:16-20. sportsci.org/2007/wghinf.htm.

24. Hopkins W. Magnitude-Based Decisions. *Sportscience*. 2019;23:i–iii. sportsci.org/2019/inbrief.htm

25. Kyprianou E, Lolli L, Haddad Al H, et al. A novel approach to assessing validity in sports performance research: integrating expert practitioner opinion into the statistical analysis. *Sci Med Football*. 2019;00(00):1-6. doi:10.1080/24733938.2019.1617433.

26. Davidson M. Known-groups validity. In: *Encyclopedia of quality of life and well-being research*. Dordrecht:

Springer, Dordrecht; 2014:3481-3482. doi:10.1007/978-94-007-0753-5_1581.

27. Folland JP, Williams AG. The adaptations to strength training. *Sports Med*. 2007;37(2):145-168.

28. Kraemer WJ, Ratamess NA. Hormonal responses and adaptations to resistance exercise and training. *Sports Med*. 2005;35(4):339-361. doi:10.2165/00007256-200535040-00004.

29. Wright MD, Hurst C, Taylor JM. Contrasting effects of a mixed-methods high-intensity interval training intervention in girl football players. *J Sports Sci*. 2016;34(19):1808-1815. doi:10.1080/02640414.2016.1139163.

30. Mclaren SJ, Graham M, Spears IR, Weston M. The sensitivity of differential ratings of perceived exertion as measures of internal load. *Int J Sports Physiol Perform*. 2016;11(3):404-406. doi:10.1123/ijspp.2015-0223.

31. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle. *Sports Med*. 2013;43(5):313-338. doi:10.1007/s40279-013-0029-x.

32. Chia M. Power recovery in the Wingate anaerobic test in girls and women following prior sprints of a short duration. *Biol Sport*. 2001;18(1):45-53.

33. Wright MD, Innerd A. Application and interpretation of the yo-yo intermittent recovery test to the long-term physical development of girls association football players. *Sci Med Football*. 2019;00(00):1-10. doi:10.1080/24733938.2019.1609071.

34. Cook J, Hislop J, Adewuyi T, et al. Assessing methods to specify the target difference for a randomised controlled trial: DELTA (Difference ELicitation in TriAls) review. *Health Technol Asses*. 2014;18(28):1-202. doi:10.3310/hta18280.