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Complete List of Authors:	Martinho, Diogo V.; University of Coimbra Rebelo, André; Universidade Lusófona de Humanidades e Tecnologias, CIDEFES, Centro de Investigação em Desporto, Educação Física e Exercício e Saúde Field, Adam ; Department of Sport and Exercise Science, Manchester Metropolitan University, Manchester, UK Ribeiro, Alex; University of Coimbra, Research Unity in Sport and Physical Activity (CIDAF, UID/DTP/04213/2020), Faculty of Sport Sciences and Physical Education, PT Pereira, FIlipa; University of Coimbra Bizarro, Bruno; University of Coimbra Ribeiro, João; Research Centre in Sports Sciences, Health Sciences and Human Development, University Institute of Maia, Portugal; Department of Performance Optimization, GOD, Sporting Clube de Braga SAD, Portugal Len, Silvano; Universidad de Ciencias de la Cultura Física y el Deporte Manuel Fajardo Gouveia, Élvio; University of Madeira, Department of Physical Education and Sport; Universidade da Madeira Madeira Interactive Technologies Institute, Laboratory of Robotics and Engineering Systems Sarmento, Hugo; Faculty of Sport Sciences and Physical Education, University of Coimbra, Portugal,
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Diogo V. Martinho*[1,2], André Rebelo[3,4], Adam Field[5], Alex Ribeiro[1], Filipa Pereira[1], Bruno Bizarro[1], João Ribeiro[6,7], Silvano M. Len[8], Élvio R. Gouveia[2,9], Hugo Sarmento[1]

[1]University of Coimbra, Faculty of Sport Sciences and Physical Education, Coimbra, Portugal
[2]Laboratory of Robotics and Engineering Systems, Interactive Technologies Institute, Funchal, Portugal
[3]CIDEFES, Centro de Investigação em Desporto, Educação Física e Exercício e Saude, Universidade Lusófona, Lisboa, Portugal
[4]COD, Center of Sports Optimization, Sporting Clube de Portugal, Lisboa, Portugal
[5]Department of Sport and Exercise Science, Manchester Metropolitan University, Manchester, UK
[6]Research Centre in Sports Sciences, Health Sciences and Human Development, University Institute of Maia, Portugal
[7]Department of Performance Optimization, GOD, Sporting Clube de Braga SAD, Portugal
[8]Universidad de Ciencias de la Cultura Física y el Deporte, La Habana, Cuba
[9]Department of Physical Education and Sport, University of Madeira, Funchal, Portugal

*Contact author:
Diogo V. Martinho
dvmartinho92@hotmail.com

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Abstract

Purpose: The monitoring of training loads and quantification of physical performance is common practice in youth soccer academies to support coaches in prescribing and programming training for individuals. The interaction between training load and physical performance is unknown during a preseason period in youth soccer players. The current study assessed changes in training load and physical assessments across a 4-week preseason period. The relationship between physical performance and match playing time in youth male soccer players was also investigated.

Methods: The training load of 25 professional youth academy male soccer players were monitored throughout a four-week preseason period. Assessments of power, agility, speed and aerobic capacity were undertaken in the first training session. Session ratings of perceived exertion (sRPE) and wellbeing questionnaires were collected during all training sessions and preseason matches. Playing time during subsequent competitive matches was recorded.

Results: T-test and 30-m sprint assessments, conducted on the first day of preseason, were predictors of sRPE throughout preseason (t-test: $\chi 2/df = 2.895$; poor adjustment; 30-m sprint: $\chi 2/df = 1.608$; good adjustment). Yoyo test performance was related with changes in perceived fatigue ($\chi 2/df = 0.534$; very good adjustment). Faster players reported higher values of sRPE, and players with higher aerobic capacity reported higher levels of fatigue across preseason. Wellbeing, perceived fatigue, soreness and sRPE decreased across preseason. Greater match durations were related to higher levels of fatigue during preseason ($p<0.05$).

Conclusion: The current study highlights the relationship between training load, physical assessments and playing time. Coaches and practitioners can use physical test data at the start of preseason as an indication of players that report higher sRPE, perceived fatigue and reduced wellbeing across preseason, supporting decisions around individualized training prescriptions.

Keywords: athlete monitoring, load management, physical assessment, recovery

Introduction

In recent years, there has been an increase in the profile of youth soccer[1,2]. According to recent data derived from 27 European countries, more than half a million U14 year old participants compete in soccer[3]. However, given the rapid annual changes in growth and maturation[4], injury propensity and overreaching in adolescent athletes is higher versus both adults and younger athletes[5,6]. Therefore, an appropriate balance between training, competition and recovery is required to minimize injury risk and overreaching in youth soccer[2]. Injury susceptibility and overreaching in youth soccer players is also likely attributed to seasonal variations in load, with peaks in injury observed following periods of inactivity or during rapid spikes in training load[7], such as during a soccer preseason[7]. Accordingly, there is growing concern relating to heightened injury and overreaching due to high training loads across certain periods within a season in youth soccer[8]. Attempts to quantify the accumulated weekly in-season training load undertaken by young soccer players have been made[9]. A separate investigation has also assessed the in-season changes in physical qualities of elite youth soccer players according to maturity status[10]. However, there is a lack of research quantifying training and match loads across a preseason period in youth soccer players.

Training loads can be measured through external or internal load, depending on whether measurements are external or internal to the athlete[11]. External loads relate to the objective measurements of physical work (e.g., distances, speeds, number of movements)[12], whereas internal load refers to the stress imposed on the athlete[11]. For example, the quantification of internal training load is commonly assessed among youth soccer players using session ratings of perceived exertion (sRPE), with wellbeing questionnaires used to assess the response to training loads[13,14]. Significant correlations between physical performance (i.e., sprint, total distance, maximum speed, average speed) and ratings of perceived exertion (RPE) in training sessions have been found in adolescent soccer players examined during six weeks of preseason[15]. However, how these relationships change when match-play is considered and how external load is linked with internal load and changing perceptions of wellbeing (measured via questionnaires) remains unknown in youth soccer players[16]. Constructs of wellbeing ratings and sRPE are sensitive to seasonal variations[17,18] and play a key role in the planning and periodization of training in soccer. Evidence demonstrating correlations between physical performance, and internal load and wellbeing measures might support soccer academy practitioners in training load management and scheduling throughout preseason.

It appears that practitioners currently prescribe preseason training intensities based on physical performance tests early in preseason[19,20], with limited understanding of how these physical qualities relate to subsequent internal load, and perceptions of fatigue and wellbeing during a youth soccer preseason. Although using physical assessments to inform training may have merit, it may not be optimal practice as although some players may perform well on an isolated test, they may subsequently demonstrate higher levels of fatigue or wellbeing during an intense preseason period. This may be particularly prevalent in youth populations given their biological immaturity, with an oversight of internal load and wellbeing potentially being detrimental in relation to both acute and recurrent injury risk, leading to future health implications[21]. Therefore, without an understanding of how speed, power, aerobic capacity, and agility correspond with internal training load and wellbeing responses, decisions on subsequent training prescriptions in youth soccer players during preseason are not as well-informed.

The aims of the study were to i) examine the relationship between physical performance at the start of the pre-season period, and internal load and well-being experienced throughout, and ii) assess whether relationships exist between internal training load and wellbeing during preseason and match playing time of matches.

Methods

The current project followed the Declaration of Helsinki and was approved by the Ethical Committee from the University of Lisbon Faculty of Human Kinetics (CEIFMH, No. 34/2021). All participants were registered with the Portuguese Soccer Federation. The youth players and legal guardians received detailed information about the study and provided informed consent before participation.

Sample and procedures

The sample included 25 male youth soccer players (age: 13.3 ± 0.3 years, stature: 1.61 ± 0.01 m, mass: 49 ± 10 kg) affiliated with the same professional soccer academy. Goalkeepers were excluded from the present study. The duration of the preseason training period for the youth soccer club was six weeks in total (August–September of the 2022−2023 season). Training load and wellbeing data were collected from players during the latter four-week period of preseason. A decision was taken to include data from this specific 4-week period of preseason given that inconsistencies in player attendance were evident during the initial 2-weeks of preseason. A training and match schedule with short descriptions of each training session is provided (Supplementary Material 1). The players completed a battery of physical tests on the first day of preseason. Within the latter four weeks of preseason, players were assessed across fifteen training days and five friendly matches. A total of 575 observations were obtained (~23 per participant). Playing time of the four official matches for each participant were recorded by the performance analyst. Data were organized into week one, two, three and four, and differences reported between weeks.

Session rating of perceived exertion

Internal training load measures were obtained 15−20 minutes following training sessions and matches using the Borg 10-point scale. Players answered the question "How hard was the session?" using a mobile application[22]. This strategy minimizes potential sources of error, including colleague influences and replication of data. The RPE rating was multiplied by the session minutes to determine the s-RPE[23].

Wellbeing questionnaire

The wellbeing questionnaire[24] was completed on a mobile application during the morning of training and match days. The tool includes five dimensions – sleep (time and quality), fatigue (herein referred to as 'perceived fatigue' or 'perceptions of fatigue'), soreness and stress – on a five-point Likert scale[25]. Wellbeing was obtained by summing the five dimensions.

Physical performance measures

A standardized warm-up consisting of running drills and dynamic stretches was executed before the physical performance measures were taken. The first assessments involved squat and countermovement jumps as indicators of power. For the squat jump, the participant adopted a half-squat position with hands on hips and were instructed to jump as fast as possible and to jump for maximum height, with a 2 s pause between the eccentric and concentric phases of each repetition. Identical verbal prompts were provided for the countermovement jump, with hands also maintained on hips, but with players initiating the movement in a fully extended position (i.e., trunk and knees at 0°) before the countermovement phase. An electronic mat (Globus Ergo Tester, Codognè, Italy) was used to obtain jump height (cm) and flight time (s). Three efforts of each jump variant were performed with a 60 s passive rest period between efforts. Following a 5-min break, agility was measured using the T-test on synthetic turf. Participants navigated cones placed in a t-shaped route as quickly as possible. The time for each effort was collected to the nearest 0.01 s with a digital chronometer connected to photoelectric cells (Globus Ergo Timer Timing System, Codogné, Italy). The best of three efforts was presented for analyses. Jumping and agility measures were taken in the morning.

Following an extensive passive rest period and re-warmup (identical to the warmup described previously), maximal 10- and 30-m sprint was performed in the afternoon to assess sprint speed using photoelectric cells (Globus Ergo Timer Timing System, Codogné, Italy). Two sprints were performed for each distance, separated by 60 s of passive rest, and the best time was retained for analyses. Following a 5-min rest, the Yoyo Intermittent Recovery Test (level 1) was used to assess aerobic capacity[26]. An audio signal controlled the speed of progressively increasing shuttle run speeds between 2x20 m cones, which were interspersed with a 10-s active recovery. The test continued until exhaustion and the player was unable to perform at the required speeds; at which point the test scores were recorded. Assessments were completed individually, aside from the Yoyo test, which involved all the team completing the assessment at the same time.

Statistical analysis

Intra and inter-individual variation across preseason were tested using the latent growth curve model[27]. The model estimated two latent parameters: intercept (α) and slope (β). The intercept represents the values at baseline (week 1), whilst the slope refers to the trajectories of load and wellbeing across preseason. Intercepts (α) were fixed as 1, and the β ranged between 0 (week 1) and 1 (week 4). The slopes of week 2 and week 3 were not defined since non-linear trajectories of load and wellbeing was expected. For these variables, simple or non-conditioning growth latent models were developed. The significance of variance for intercept and slope indicated inter-individual variability at baseline (week 1) and distinct weekly trajectories for load and wellbeing variables included in the models, respectively. The covariance between intercept and slope indicates a relationship between values at week 1 and the level of growth for subsequent weeks. Significant variance for slope and intercept indicated inter-individual variability. Explanatory or exogenous variables were included in the model to explain inter-individual variability derived from simple models. Exogenous variables were physical tests assessed on the first day of preseason and playing time of matches. Dummy variables were created based on the mean value (1-below and 2-above mean). Conditioning models incorporated physical tests or playing time as exogenous variables, and the α and β were defined as latent variables. Three different strategies were used to test the impact of exogenous variables: (1) a multigroup analysis was performed to verify the impact of exogenous variables; (2) an interpretation normalized chi-squared ($\Delta\chi 2/df$; $5<\chi 2/df$, poor adjustment; $2<\chi 2/df \leq 5$, reasonable adjustment; $1<\chi 2/df \leq 2$, good adjustment; and $\chi 2/df$ approximately 1, very good adjustment)[27]; (3) a reduction in the variance of latent parameters (i.e. constant and slope) demonstrated a substantial reduction in interindividual variation[28]. Significant models are included in the results section. Statistical analyses were conducted with the computer software IBM SPSS AMOS (version 28.0). Significance was set at $p \leq 0.05$.

Results

The mean of the slope indicates the tendency for changes. As reported in Table 1, sRPE, wellbeing, perceived fatigue and soreness were decreased across the four weeks of preseason (i.e. the mean slope was negative for all parameters). Differences between players were found for sRPE (V(intercept)=2.982, p<0.01), wellbeing (V(intercept)=0.06, p=0.01), perceived fatigue (V(intercept)=0.0232, p<0.01) and soreness (V(intercept)=0.09, p<0.01) at baseline (week 1). Substantial inter-individual variation (i.e., differences between players) was also found across the four weeks of pre-season for perceived fatigue (V(slope)=0.241, p=0.02) and soreness (V(slope)=0.074, p=0.04). A significant covariance between intercept and slope was noted for perceived fatigue (-0.22, p=0.01) and soreness (-0.05, p=0.07). The negative coefficient indicates that players who reported higher values of perceived fatigue or soreness at baseline (week 1) reported smaller fluctuations in these variables across the preseason period. Figures 1 illustrates fluctuations (panel A and C) and intra-individual changes (panel B and D) in sRPE and wellbeing.

[Table 1 – about here]
[Figure 1 – about here]

Physical performance and playing time are reported in Table 2. Figure 2 (panel A, B and, C) represents the conditioning models with exogenous variables (physical tests) as potential predictors of growth latent models, with solely the significant models presented. T-test and 30-m sprint, measured on day one of preseason are related with changes in sRPE throughout preseason (t-test: $\chi2/df = 2.895$; poor adjustment; 30-m sprint: $\chi2/df = 1.608$; good adjustment). The Yoyo test was associated with changes in perceived fatigue ($\chi2/df = 0.534$; very good adjustment). In these models, the error decreased compared with simple models (variance is presented in Table 1). The negative standardized slope presented in Figure 2 for the t-test and 30-m sprint assessment, demonstrated that faster players reported higher values of sRPE. Players who performed better on the Yoyo test also reported higher levels of perceived fatigue across preseason. The variability of pre-season indicators on playing time (obtained in four competitive matches) was tested. Only the significant model was represented (Figure 2 – panel D). Variation in perceived fatigue measured during preseason impacted on playing time in the four subsequent matches (i.e., higher perceptions of fatigue during the preseason period were related with longer playing durations – the slope is positive). All constrained models were significant ($p < 0.05$).

[Table 2 – about here]
[Figure 2 – about here]

Discussion

The findings of this study evaluated changes in internal training load across preseason and the relationships between physical tests and internal training load in youth soccer players. The results suggest that sRPE, wellbeing, perceived fatigue, and soreness values decreased as a function of time over a four-week preseason period. Inter-individual variations in fatigue and soreness highlighted the heterogeneity in players' responses to training. Agility and sprint tests were predictors of sRPE, demonstrating that faster players perceived higher exertion during seasons throughout preseason. Higher Yoyo test results correlated with greater fatigue during preseason. This suggests that those with greater aerobic capacity at the beginning of the season reported higher perceptions of fatigue throughout preseason. Perceived fatigue was also higher for the players with greater playing time in preseason matches (i.e., those that completed greater match durations reported higher level of fatigue). The findings can be used for preparing and monitoring youth soccer players during preseason.

The positive correlation between agility, speed and perceived exertion aligns with previous findings that suggests physical fitness is closely related to perceived training difficulty in youth soccer players[29]. While enhanced aerobic performance was associated with increased playing time, it was also correlated with greater perceptions of fatigue, warranting further investigation. This suggests that players producing superior Yoyo test scores, subsequently report higher fatigue throughout preseason. Interestingly, those with superior Yoyo performance were also slower according to the linear sprint speed and agility data. This is likely attributed to muscle fiber type composition since slow-twitch muscle fibres are more resistant to fatigue than fast-twitch fibers, but are incapable of producing high contraction speeds[30]. It is also plausible that this finding could reflect that those with a greater aerobic capacity also complete a greater quantity of activity during training and matches than those that are less aerobically conditioned, hence explaining the higher perceptions of fatigue. This may indicate an optimal balance that must be maintained between internal training load, player readiness, and recovery in soccer[31,32]. The positive relationship between greater aerobic capacity and perceptions of fatigue, emphasizes the need for a comprehensive understanding of individual player responses to internal training load and highlights the importance of monitoring fatigue as a predictor of fatigue and match performance[33,34].

The intra and inter-individual changes in sRPE, fatigue, soreness, and wellbeing emphasize the importance of individualized training programs to manage training loads in young soccer players during preseason[35,36]. This is supported by the inter-individual variations in fatigue and soreness, which suggests that a one-size-fits-all approach to preseason training may not be effective for youth soccer players. Therefore, tailoring preseason training to an individual players' needs and capacities may enhance wellbeing and performance of soccer players[37]. The finding that increased playing time in subsequent matches was related with higher perceptions of fatigue is a novel finding that suggests a multifaceted interaction between training, recovery, and competitive readiness. Players would be unlikely to sustain activity at the required intensity when experiencing fatigue[38]. Therefore, based on the findings, practitioners, coaches, and medical staff in academies may consider monitoring the duration of training and matches of each player to identify the those that perhaps require additional aerobic training.

The current study provides meaningful insights into physical performance and training loads in youth soccer players, yet there are several limitations that must be considered. While the measurement tools used are widely accepted, they may have intrinsic limitations. For example, self-reported measures such as wellbeing questionnaires might be influenced by reporting bias, and the use of tests like the Yoyo Intermittent Recovery Test Level 1 may not capture all aspects of players' fitness. The study did not directly assess offseason training programs, leaving an area unexplored that could provide valuable insights into preparation and performance. The focus on a single preseason may overlook potential long-term developmental aspects and the cumulative effects of sequential seasons on player performance and wellbeing. Further investigations that include more diverse samples and direct examinations of offseason training could lead to a more comprehensive understanding of youth soccer players.

Practical applications

The findings of the current study offer valuable applications for coaches, players, and academics. The observed correlation between the Yoyo test performance and subsequent playing time emphasizes the significance of aerobic capacity in youth soccer. It is likely that players with higher aerobic capacity have enhanced physical outputs, and as such, undertake a greater quantity of actions and technical involvements, resulting in them being selected more frequently by the coach. This is substantiated given that technical performance has shown to decline between the first and second half in line with physical fatigue[39]. Coaches can use this information to design their training protocols, particularly in the preseason and offseason. For instance, incorporating exercises that improves aerobic endurance might enhance a player's match time in the competitive season. Given the ease of application for the Yoyo test, it serves as a practical tool to monitor players' fitness levels throughout the season. The study also highlighted the importance of managing load effectively, with coaches advised to pay careful attention to players' perceived exertion and signs of fatigue. The use of wellbeing questionnaires could also be a valuable tool, enabling more objective monitoring of players' responses to training and competition.

These results also possess implications for the offseason period. The offseason is typically used as a time for rest and recovery; however, the findings suggest it may be useful for preparing youth soccer players for the demands of the competitive season akin with previous guidelines[40]. Training programs designed for the offseason that focus on enhancing aerobic capacity could be vital in optimizing player readiness for preseason training and matches, enabling higher intensities during play[25]. The importance of training during the offseason emphasizes the need for coaches and sports scientists to take a year-round view of player development, rather than seeing the offseason solely as downtime[41]. The present study corroborates the need for further research into youth soccer training and performance, such as through longitudinal studies tracking training loads over multiple seasons in youth soccer players.

Conclusion

The present study reveals relationships between preseason physical tests, internal load parameters, and playing time during preseason in youth soccer players. The data suggests that sRPE, perceived fatigue and soreness increase across the preseason period. Heterogeneity in perceived fatigue and soreness were apparent, with players that report higher perceptions of fatigue and soreness on the first day of preseason, experiencing smaller fluctuations in these variables across preseason. This suggests that players should utilize the offseason period to ensure they are prepared and conditioned for preseason, perhaps leading to lesser ratings of fatigue and soreness throughout this period. These findings suggest that individualized training programs and careful management of internal training load are required. The results of this study enrich our understanding of youth soccer preparation and performance, offering applications for practitioners and directions for future research. The insights provided could lead to more effective training programs, enhanced player wellbeing, and elevated performance.

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References

1. Clemente FM, Sarmento H, Costa IT, Enes AR, Lima R. Variability of Technical Actions During Small-Sided Games in Young Soccer Players. *J Hum Kinet*. 2019;69:201-212. doi:10.2478/hukin-2019-0013

2. Sarmento H, Clemente FM, Harper LD, Costa ITD, Owen A, Figueiredo AJ. Small sided games in soccer–a systematic review. *Int J Perform Anal Sport.* 2018;1*8*(5):693-749.

3. Emmonds S, Till K, Weaving D, Burton A, Lara-Bercial S. Youth Sport Participation Trends Across Europe: Implications for Policy and Practice [published online ahead of print, 2023 Jan 25]. *Res Q Exerc Sport*. 2023;1-12. doi:10.1080/02701367.2022.2148623

4. Emmet D, Roberts J, Yao KV. Update on preventing overuse injuries in youth athletes. *Curr. Phys. Med. Rehabil.* 2022;*10*(3), 248-256.

5. Towlson C, Salter J, Ade JD, et al. Maturity-associated considerations for training load, injury risk, and physical performance in youth soccer: One size does not fit all. *J Sport Health Sci*. 2021;10(4):403-412. doi:10.1016/j.jshs.2020.09.003

6. van der Sluis A, Elferink-Gemser MT, Coelho-e-Silva MJ, Nijboer JA, Brink MS, Visscher C. Sport injuries aligned to peak height velocity in talented pubertal soccer players. *Int J Sports Med*. 2014;35(4):351-355. doi:10.1055/s-0033-1349874

7. Read PJ, Oliver JL, De Ste Croix MB, Myer GD, Lloyd RS. The scientific foundations and associated injury risks of early soccer specialisation. *J Sports Sci*. 2016;34(24):2295-2302. doi:10.1080/02640414.2016.1173221

8. Bergeron MF. Youth sports in the heat: recovery and scheduling considerations for tournament play. *Sports Med*. 2009;39(7):513-522. doi:10.2165/00007256-200939070-00001

9. Wrigley R, Drust B, Stratton G, Scott M, Gregson W. Quantification of the typical weekly in-season training load in elite junior soccer players. *J Sports Sci*. 2012;30(15):1573-1580. doi:10.1080/02640414.2012.709265

10. Johnson DM, Cumming SP, Bradley B, Williams S. How much training do English male academy players really do? Load inside and outside of a football academy. *Int J Sports Sci Coach*. 2023;18(4):1123–1131. doi:10.1177/17479541221101847

11. 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

12. Jaspers A, Brink MS, Probst SG, Frencken WG, Helsen WF. Relationships Between Training Load Indicators and Training Outcomes in Professional Soccer. *Sports Med*. 2017;47(3):533-544. doi:10.1007/s40279-016-0591-0

13. Noon MR, James RS, Clarke ND, Akubat I, Thake CD. Perceptions of well-being and physical performance in English elite youth footballers across a season. *J Sports Sci*. 2015;33(20):2106-2115. doi:10.1080/02640414.2015.1081393

14. Rodríguez-Marroyo JA, Antoñan C. Validity of the session rating of perceived exertion for monitoring exercise demands in youth soccer players. *Int J Sports Physiol Perform*. 2015;10(3):404-407. doi:10.1123/ijspp.2014-0058

15. Lechner S, Ammar A, Boukhris O, et al. Monitoring training load in youth soccer players: effects of a six-week preparatory training program and the association between external and internal loads. *Biol Sport*. 2023;40(1):63-75. doi:10.5114/biolsport.2023.112094

16. Schmikli SL, Brink MS, de Vries WR, Backx FJ. Can we detect non-functional overreaching in young elite soccer players and middle-long distance runners using field performance tests?. *Br J Sports Med*. 2011;45(8):631-636. doi:10.1136/bjsm.2009.0674627

17. Noon MR, James RS, Clarke ND, Akubat I, Thake CD. Perceptions of well-being and physical performance in English elite youth footballers across a season. *J Sports Sci*. 2015;33(20):2106-2115. doi:10.1080/02640414.2015.1081393

18. Fanchini M, Ferraresi I, Modena R, Schena F, Coutts AJ, Impellizzeri FM. Use of CR100 Scale for Session Rating of Perceived Exertion in Soccer and Its Interchangeability With the CR10. *Int J Sports Physiol Perform*. 2016;11(3):388-392. doi:10.1123/ijspp.2015-0273

19. Morris R, Emmonds S, Jones B, Myers TD, Clarke ND, Lake J, Ellis M, Singleton D, Roe G, Till K. Seasonal changes in physical qualities of elite youth soccer players according to maturity status: comparisons with aged matched controls. Sci. Med Footb. 2018;2(4):272-80.

20. McQuilliam SJ, Clark DR, Erskine RM, Brownlee TE. (2023). Physical testing and strength and conditioning practices differ between coaches working in academy and first team soccer. Int J Sports Sci Coach. 2013;18(4):1045–1055. doi:10.1177/17479541231155108

21. Swain M, Kamper SJ, Maher CG, Broderick C, McKay D, Henschke N. Relationship between growth, maturation and musculoskeletal conditions in adolescents: a systematic review. *Br J Sports Med*. 2018;52(19):1246-1252. doi:10.1136/bjsports-2017-098418

22. Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med*. 1970;2(2):92-98.

23. Foster C, Boullosa D, McGuigan M, et al. 25 Years of Session Rating of Perceived Exertion: Historical Perspective and Development. *Int J Sports Physiol Perform*. 2021;16(5):612-621. doi:10.1123/ijspp.2020-0599

24. Hooper SL, Mackinnon LT. Monitoring overtraining in athletes. Recommendations. *Sports Med*. 1995;20(5):321-327. doi:10.2165/00007256-199520050-00003

25. McLean BD, Coutts AJ, Kelly V, McGuigan MR, Cormack SJ. Neuromuscular, endocrine, and perceptual fatigue responses during different length between-match microcycles in professional rugby league players. *Int J Sports Physiol Perform*. 2010;5(3):367-383. doi:10.1123/ijspp.5.3.367

26. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test : a useful tool for evaluation of physical performance in intermittent sports. *Sports Med*. 2008;38(1):37-51. doi:10.2165/00007256-200838010-00004

27. Byrne BM. Structural EquationModeling with AMOS: Basic Concepts, Applications, and Programming. New York, NY: Routledge; 2016.

28. Marôco J. Análise de equações estruturais: Fundamentos teóricos, software & aplicações. ReportNumber, Lda; 2014.

29. Gil-Rey E, Lezaun A, Los Arcos A. Quantification of the perceived training load and its relationship with changes in physical fitness performance in junior soccer players. *J Sports Sci*. 2015;33(20):2125-2132. doi:10.1080/02640414.2015.1069385

30. Lievens E, Van Vossel K, Van de Casteele F, et al. Muscle Fibre Typology as a Novel Risk Factor for Hamstring Strain Injuries in Professional Football (Soccer): A Prospective Cohort Study. *Sports Med*. 2022;52(1):177-185. doi:10.1007/s40279-021-01538-2

31. Figueiredo DH, Figueiredo DH, Moreira A, Gonçalves HR, Dourado AC. Dose-Response Relationship Between Internal Training Load and Changes in Performance During the Preseason in Youth Soccer Players. *J Strength Cond Res*. 2021;35(8):2294-2301. doi:10.1519/JSC.0000000000003126

32. Pereira LA, Freitas TT, Zanetti V, Loturco I. Variations in Internal and External Training Load Measures and Neuromuscular Performance of Professional Soccer Players During a Preseason Training Period. *J Hum Kinet*. 2022;81:149-162. Published 2022 Feb 10. doi:10.2478/hukin-2022-0012

33. Halson SL. Monitoring training load to understand fatigue in athletes. *Sports Med*. 2014;44 Suppl 2(Suppl 2):S139-S147. doi:10.1007/s40279-014-0253-z

34. Thorpe RT, Atkinson G, Drust B, Gregson W. Monitoring Fatigue Status in Elite Team-Sport Athletes: Implications for Practice. *Int J Sports Physiol Perform*. 2017;12(Suppl 2):S227-S234. doi:10.1123/ijspp.2016-0434

35. Douchet T, Paizis C, Carling C, Cometti C, Babault N. Typical weekly physical periodization in French academy soccer teams: a survey. *Biol Sport*. 2023;40(3):731-740. doi:10.5114/biolsport.2023.119988

36. Marynowicz J, Kikut K, Lango M, Horna D, Andrzejewski M. Relationship Between the Session-RPE and External Measures of Training Load in Youth Soccer Training. *J Strength Cond Res*. 2020;34(10):2800-2804. doi:10.1519/JSC.0000000000003785

37. Ramírez-Campillo R, Meylan C, Alvarez C, et al. Effects of in-season low-volume high-intensity plyometric training on explosive actions and endurance of young soccer players. *J Strength Cond Res*. 2014;28(5):1335-1342. doi:10.1519/JSC.0000000000000284

38. Reilly T, Drust B, Clarke N. Muscle fatigue during football match-play. *Sports Med*. 2008;38(5):357-367. doi:10.2165/00007256-200838050-00001

39. Rampinini E, Impellizzeri FM, Castagna C, Coutts AJ, Wisløff U. Technical performance during soccer matches of the Italian Serie A league: effect of fatigue and competitive level. *J Sci Med Sport*. 2009;12(1):227-233. doi:10.1016/j.jsams.2007.10.002

40. Lyakh V, Mikołajec K, Bujas P, Witkowski Z, Zając T, Litkowycz R, Banyś D.. Periodization in team sport games-A review of current knowledge and modern trends in competitive sports. *J Hum Kinet*. 2016;*54*:173.

41. Clemente FM, Ramirez-Campillo R, Sarmento H. Detrimental Effects of the Off-Season in Soccer Players: A Systematic Review and Meta-analysis. *Sports Med*. 2021;51(4):795-814. doi:10.1007/s40279-020-01407-4

Figure legend

Figure 1. Session ratings of perceived exertion (panel A) and wellbeing (panel C) in addition to intra-individual changes across the four weeks of the pre-season (panels B and D).

Figure 2. Latent growth curve models for session ratings of perceived exertion and fatigue.

Table 1. Latent growth models for session ratings of perceived exertion, well-being, fatigue and soreness

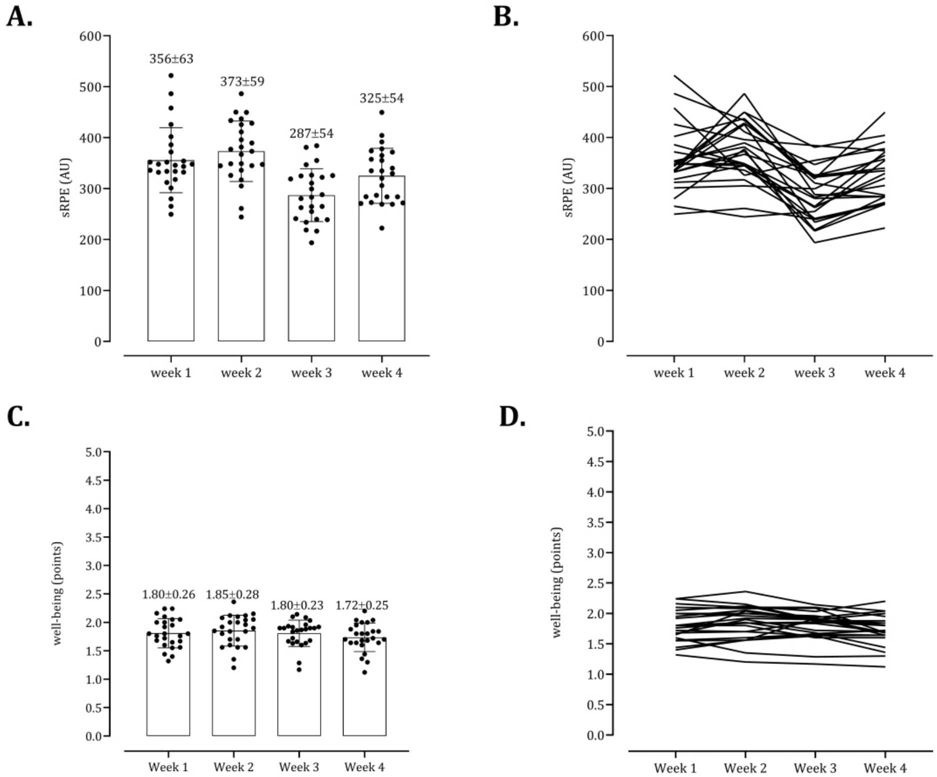
Simple model	**sRPE**	**well-being**	**fatigue**	**soreness**
Intercept				
mean	356.2 (p<0.01)	1.832 (p<0.01)	2.347 (p<0.01)	31.1 (p<0.01)
variance	2.892 (p<0.01)	0.06 (p=0.01)	0.232 (p<0.01)	0.09 (p<0.01)
Slope				
mean	-29.36 (p=0.01)	-0.09 (p<0.01)	-0.292 (p=0.01)	-2.073 (p<0.01)
variance	-55.2 (p=0.62)	0.01 (p=0.15)	0.241 (p=0.02)	0.074 (p=0.04)
Intercept and slope				
covariance	3.11 (p=0.98)	-0.10 (p=0.25)	-0.22 (p=0.01)	-0.05 (p=0.07)

sRPE (session rating of perceived exertion)

Table 2. Physical performance responses on the first day of preseason and playing time throughout the matches during preseason

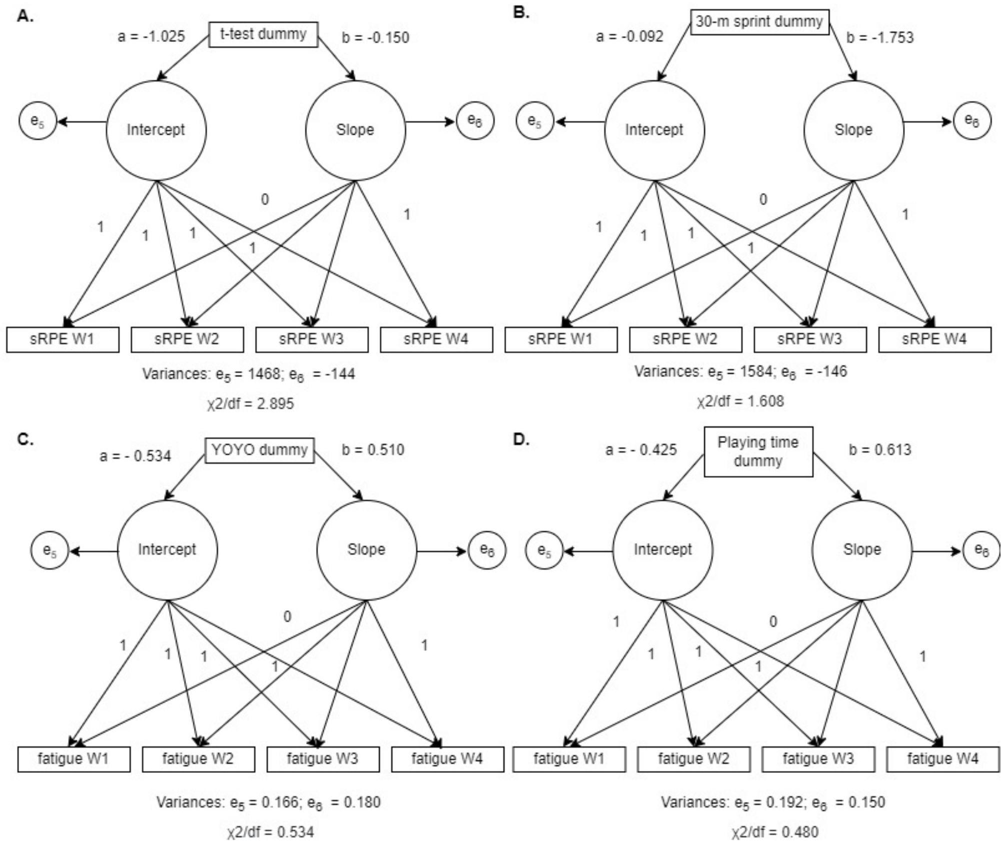
Variable	Descriptive statistics	
	Mean ± SD (95% CI)	**SEM**
Squat jump (cm)	30.7 4.4 (28.8 to 32.5)	0.8
Countermovement jump (cm)	30.5 ± 3.5 (29.1 to 32.0)	0.7
T-test (s)	10.2 ± 0.3 (10.0 to 10.4)	0.06
Yoyo Intermittent Recovery Test (level)	26 ± 6 (24 to 29)	1.1
Playing time (min)	32.5 ± 25.2 (20.8 to 42.8)	5.2

95% CI (95% confidence intervals), SEM (standard error of mean)



Session ratings of perceived exertion (panel A) and wellbeing (panel C) in addition to intra-individual changes across the four weeks of the pre-season (panels B and D).

234x206mm (600 x 600 DPI)



Latent growth curve models for session ratings of perceived exertion and fatigue.

283x244mm (72 x 72 DPI)

Supplementary Material 1. Training and match schedule over the last 4-weeks of preseason.

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	**Rest**	**Training** (small-sided games)	**Training** (offensive and defensive organization and1 vs. 1 contests)	**Training** (tactical drills during a match scenario)	**Training** (speed drills and offensive organization)	**Training** (offensive pressing drill)
2	**Rest**	**Rest**	**Training** (positional drills)	**Training** (M) (individual technique training and timings of entry in deep space **Match** (A)	**Training** (offensive pressing drill and organization from goal kicks)	**Match** (A)
3	**Rest**	**Training** (defending crosses and timing of finishing)	**Training** (positional drills)	**Training** (offensive organization)	**Training** (speed drills)	**Rest**
4	**Rest**	**Training** (small-sided games)	**Training** (tactical drills during a match scenario)	**Training** (offensive pressing drill and organization from goal kicks)	**Match** (A)	**Match** (M) **Match** (A)

M (morning), A (afternoon).