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EFFECTS OF ADDITIONAL REPEATED SPRINT TRAINING ON HEART RATE VARIABILITY IN SOCCER PLAYERS DURING THE COMPETITIVE SEASON

UČINCI DODATNOG TRENINGA PONAVLJANIH SPRINTEVA NA VARIJABILNOST SRČANE FREKVENCIJE KOD NOGOMETAŠA TIJEKOM NATJECATELJESKE SEZONE

Almin Hopovac
Faculty of Kinesiology University of Zagreb, 10 000 Zagreb, Croatia

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Corresponding author: Almin Hopovac, almin.hopovac@gmail.com
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ABSTRACT

Heart rate variability (HRV) has become a useful method to screen, monitor and track physical preparedness for optimal performance. Although it has been widely used in sports practice, little is known about its variation following a repeated sprint ability (RSA) training. Therefore, the main purpose of the study was to examine the effects of the RSA on HRV in soccer players.

Twenty professional soccer players participated in a 6-week additional repeated sprint training program during the competitive season, which included 1-2 X 6-8 sprints in 25-meter length intervals with a resting period of 25 seconds two times per week. The HRV for each week was calculated using the natural logarithm of the square root of the mean squared difference of successive R-R intervals (LnRMSSD).

Over a 6-week period, no significant ‘time’ ($F_{5,120}$ = 0.348, P = 0.883), ‘group’ ($F_{1,120}$ = 0.105, P = 0.747) and ‘time*group’ interaction ($F_{5,120}$ = 0.433, P = 0.825) for LnRMSSD were observed. Based on the group, EXP exhibited more stable LnRMSSD up to week 5, after which LnRMSSD decreased towards the end of the intervention. An increase-decrease pattern of LnRMSSD from week 1 till week 4 for CON was shown, with a plateau reached between week 4 and week 6.

RSA training had no significant effect on LnRMSSD in soccer players during the competitive season. Despite a decrease in LnRMSSD in the last week for EXP, the follow-up period of 6 weeks in a competitive period might not be adequately long to obtain more impactful effects on LnRMSSD.

Keywords: autonomous regulation, heart rate, team sports, sprint, intervention

SAŽETAK

Varijabilnost srčane frekvencije (HRV) postala je korisna metoda za detektiranje, nadzor i praćenje tjelesne spremnosti za optimalnu izvedbu. Iako je korištenje HRV-a široko u sportskoj praksi, malo se zna o njegovim varijacijama nakon ponovljenog treninga sprinta (RSA). Stoga je glavni cilj ovog istraživanja bio ispitati učinke RSA na HRV kod nogometaša.

Dvadeset profesionalnih nogometaša sudjelovalo je u 6-tjednom dodatnom ponovljenom programu treninga sprinta tijekom natjecateljske sezone, koji je uključivao 1-2 X 6-8 sprinta u intervalima od 25 metara s razdobljem odmora od 25 sekundi dva puta tjedno. HRV za svaki tjedan izračunao se uz pomoć prirodnog logaritma kvadratnog korijena srednje kvadratne razlike uzastopnih R-R intervala (LnRMSSD).

Tijekom razdoblja od 6 tjedana nisu primijećeni značajni glavni učinci ‘vremena’ ($F_{5,120}$ = 0.348, P = 0.883), ‘grupe’ ($F_{1,120}$ = 0.105, P = 0.747) i interakcije ‘vremena*grupe’ ($F_{5,120}$ = 0.433, P = 0.825) u LnRMSSD. S obzirom na grupu, EXP je pokazao stabilniji LnRMSSD do 5. tjedna, nakon čega se HRV smanjio prema kraju intervencije. Prikazan je obrazac povećanja-smanjenja LnRMSSDod 1. do 4. tjedna za CON, s platoom postignutim između 4. i 6. tjedna.

RSA nema značajan učinak na LnRMSSD kod nogometaša tijekom natjecateljske sezone. Unatoč smanjenju LnRMSSDu posljednjem tjednu za EXP, razdoblje praćenja od 6 tjedana u natjecateljskom razdoblju možda nije bilo dovoljno dugo da bi se postigli značajniji učinci na LnRMSSD.

Ključne riječi: autonomna regulacija, frekvencija srca, timski sportovi, sprint, intervencija

INTRODUCTION

Physiological characteristics of soccer highlight that it is a sport with a combination of short periods of high-intensity and long periods of low-intensity activities (3, 31). These high-intensity actions are referred to fast running, sprinting, accelerations, decelerations, and rapid change-of-direction movements (44). Evidence suggests that in-season period, which combines soccer matches with high training loads, represents a crucial timeframe for maintaining or further improving physical capacities (36). Among many, soccer predominantly requires repeated sprints and intermittent high-intensity exercises, speed and lower-limb muscle power to be at high level (28).

Over the last two decades, the repeated sprint ability (RSA) has been recognized as one of the most crucial components of overall fitness level in team sports (4), including soccer (8, 12, 38). RSA enables an individual to reach an adequate motor unit activation to achieve maximal speed and the ability for repeated sprints over a short period of time (8). It has been documented that better sprinters have an improved phosphocreatine resynthesis and hydrogen bursts (5), which are major physiological components for power output and optimal recovery after sprint performance (6). Thus, it is not surprising that the RSA test has been widely correlated with aerobic capacity outcomes, including fast oxygen kinetics (1), maximal oxygen uptake (VO_2max) (2, 14), blood lactate levels (20), and fatigue (26).

The effects of training can be measured by several physiological factors, with the most common ones including VO_2max, submaximal ventilatory thresholds, heart rate, and blood lactate concentration (23). However, most of them need specialized equipment to collect the data, which can be time-consuming. Heart rate variability (HRV) has become a popular training method to monitor preparedness and determine recovery in soccer (19). It relies on a connection between cardiovascular and neural systems, where HRV is partially under the control of sympathetic and parasympathetic autonomic regulatory systems (7). Since HRV gives a reliable and valid insight into the interval length between two successive heart beats in soccer players (29), the practical application of HRV is in its sensitive ability to reactivate parasympathetic system and to return the sympathetic and parasympathetic activities in balance (27).

The changes in HRV largely depend on training intensities (19, 30). The recovery of HRV becomes fast after applying low-intensity activities, such as aerobic training at 60% to 75% of maximal heart rate (43). However, activities of higher intensities (anaerobic training) may suppress parasympathetic reactivation and increase fatigue, which directly affects the level of overreaching (15). In other words, parasympathetic system needs more time to surpass the sympathetic activity and in that time frame, performance greatly deteriorates. However, findings related to the effects of RSA on HRV have yet to be investigated. Indeed, the RSA is categorized as supramaximal intensity interspersed by short recovery bouts (4, 21), but the specific neuromuscular activation during and fatigue after exercise may not be adequate to get positive feedback of HRV during the competitive period (24). Available literature indicates that competitive season in soccer is characterized by excessive physiological and mental overloading, accumulating fatigue and impairing HRV response (42). Although the additional RSA had positive effects on HRV in soccer players during pre-season period (42), it is still unknown to what extent does the additional training of RSA may affect HRV during in-season period. By examining such effects, we would get a better understanding of HRV responsiveness to RSA in competitive season and potential beneficial adaptations to training load.

Therefore, the main purpose of the study was to examine the effects of a 6-week supplemental RSA training vs. standard training on HRV in elite soccer players. Based on previous findings (9, 34, 40), we speculated that HRV would remain unchanged following the RSA training during the competitive season.

MATERIALS AND METHODS

Study participants

In this randomized 6-week follow-up study, we recruited 20 soccer players with a mean ± standard deviation (SD) (height = 181.6 ± 7.7 cm, weight = 75.5 ± 6.5 kg, body mass index = 22.9 ± 2.0 kg*m^{-2}) in one soccer club from the 1st Croatian soccer league, the highest level of competition. The 20 players were randomly assigned to a standard training group (CON; n = 10) or a group with additional RSA training (EXP; n = 10) using an online randomization calculator software (25). The researcher who made the assignment into groups had no role in study design, training methods and test assessments. According to previous studies (42), the inclusion criteria included: (i) regular participation > 90% of training sessions during the study; (ii) being free from injuries; (iii) not using any pharmaceutical drugs that could affect the outcomes; and (iv) minimum experience of at least 4 years in professional soccer. All participants had signed a written informed consent before entering the study. The procedures were anonymous and performed in accordance with the Declaration of Helsinki (45). The study was approved by the Ethical Committee of the Faculty of Kinesiology, University of Zagreb, Croatia.

HRV

To objectively assess the state of autonomic nervous system (sympathetic and parasympathetic), we calculated HRV from the recording of R-R intervals (the time between two successive R-waves on an electrocardiogram) using a heart rate monitor (Polar Electro Oy, Kempele, Finland). HRV was measured every week before the training session in a seated position during the period of 2 minutes. After recording, the software (Elite HRV) generated the data presented as weekly mean values of HRV (known as LnRMSSD) in milliseconds (ms) (37). The Elite HRV application has shown reliable and valid characteristics (r = 0.77 – 0.94) in short and very-short length measurements, compared to electrocardiogram (32).

Training sessions

The two training groups (EXP and CON) performed the same training sessions over a 6-week period, with the EXP group having an additional RSA 2x/week. The RSA training included: weeks 1 and 2: 1-2 series of 1 x 6 (week 1) and 2 x 6 (week 2) bouts of 25 m sprints with 25 seconds of rest between sprints; week 3 and 4: 1-2 series of 1 x 7 (week 3) and 2 x 7 (week 4) bouts of 25 m sprints with 25 seconds of rest between sprints; and week 5 and 6: 1-2 series of 1 x 8 (week 5) and 2 x 8 (week 6) bouts of 25 m sprints with 25 seconds of rest between sprints. The passive recovery between each session was 2 minutes each week. During the period of 6 weeks, the EXP successfully completed 126 sprints and covered 3,150 meters.

A standard part of the training consisted of physical, technical and tactical training. On Mondays, all participants completed a 1-hour resistance training which included exercises for injury prevention, polygon with the ball (15 minutes) and 20 minutes of capillarization. Tuesdays were reserved for a 40-minute warm-up circular training, after which the participants played a 4-minute x 5-session soccer match in the area 30 x 40 meters. On Thursdays, the speed, agility and quickness (SAQ) training was implemented for the development of explosive power, which included short sprints, plyometric jumps, sprints with resistance and agility (35 minutes), followed by the 45 minute of soccer match. The last day of the week (Friday) intended to improve technical-tactical abilities for the match (90 minutes). An official soccer match was played every Sunday.

Data analysis

The Kolmogorov-Smirnov test tested the normality of the distribution. Basic descriptive statistics are presented as mean and standard deviation (SD). The effects of a 6-week additional RSA on LnRMSSD were examined by 2x2 repeated analysis of variance (RMANOVA). Main effects for 'time' (pre-post measurement), 'group' (EXP vs. CON), and 'time*group' interaction (EXP-pre, EXP-post, CON-pre, CON-post) were calculated with Bonferroni *post-hoc* comparisons. If a significant main effect occurred, between and within group comparisons were examined using the Student t-test for independent and dependent samples, respectively. The Cohen's effect size (Cohen D) determined the magnitude of the change with the following threshold values: < 0.2 (trivial); 0.2 – 0.6 (small); 0.6 – 1.2 (moderate); and >1.2 (large) (22). All procedures performed in this study were calculated using Statistical Packages for Social Sciences (SPSS, ver. 26, IBM Corporation, Chicago, IL) and the significance was set at $p < 0.05$ (two-sided).

RESULTS

Basic descriptive statistics are presented in table 1. No significant differences between the EXP and CON groups were observed ($P > 0.05$). EXP group was slightly taller, heavier, and had higher body mass index values, compared to CON group. On the other hand, LnRMSSD values were higher in CON group, but the difference was only trivial (mean diff. = 0.1, 95% CI = -0.59 – 0.54, Cohen d = 0.16).

Over a period of 6 weeks, no significant differences in the main effect for 'time' were observed ($F_{5,120}$ = 0.348, P = 0.883), group ($F_{1,120}$ = 0.105, P = 0.747) and 'time*group' interaction ($F_{5,120}$ = 0.433, P = 0.825) were observed. For EXP, changes from the baseline to weeks 2-6 were as follows: week 1 → week 2 (3.4%, Cohen D = 0.26), week 1 → week 3 (2.7%, Cohen D = 0.21), week 1 → week 4 (3.7%, Cohen D = 0.26), week 1 → week 5 (1.3%, Cohen D = 0.11), and week 1 → week 6 (-4.2%, Cohen D = 0.30). Compared to week 1, LnRMSSD values increased in week 2 (4.0%, Cohen D = 0.22), week 4 (4.5%, Cohen D = 0.28), week 5 (4.3%, Cohen D = 0.25), and week 6 (4.5%, Cohen D = 0.28), while a decrease in LnRMSSD in week 3 (-1.1%, Cohen D = 0.06) was observed. A Bonferroni *post-hoc* indicated no significant differences in LnRMSSD within each group over 6 weeks, although in week 6, EXP exhibited larger declines in LnRMSSD, compared to CON group (table 2).

Table 1. Characteristics of the study participants, according to group; data are presented as mean ± SD
Tablica 1. Karakteristike ispitanika s obzirom na grupu, podaci su prikazani putem aritmetičke sredine ± SD

Study variables	Total (*n* = 20)	EXP (*n* = 10)	CON (*n* = 10)	*P* - value
Height (cm)	181.60 ± 7.70	182.50 ± 5.60	180.60 ± 9.50	0.593
Weight (kg)	75.50 ± 6.50	76.50 ± 5.00	74.10 ± 7.80	0.368
Body mass index (kg*m^{-2})	22.90 ± 2.00	23.10 ± 1.60	22.80 ± 2.30	0.735
LnRMSSD in Week 1 (ms)	3.80 ± 0.60	3.70 ± 0.70	3.80 ± 0.50	0.924

$P < 0.05$

Table 2. Weekly changes in heart rate variability (HRV) in EXP and CON groups over a 6-week period; values are presented as mean ± SD; Mean difference, Cohen's D, and P - values between-group comparisons for each week

Tablica 2. Tjedne promjene u varijabilnosti srčane frekvencije tijekom 6 tjedana u EXP i CON grupi; podaci su prikazani kao aritmetičke sredine ± SD, prosječne razlike, Cohenov D i P – vrijednosti između grupa za svaki tjedan

LnRMSSD	EXP (n = 10)	CON (n = 10)	Mean diff.	Cohen D	P - value
Week 1	3.77 ± 0.50	3.74 ± 0.70	-0.03	0.16	0.924
Week 2	3.90 ± 0.44	3.89 ± 0.68	-0.02	0.02	0.951
Week 3	3.87 ± 0.38	3.70 ± 0.55	-0.17	0.36	0.447
Week 4	3.91 ± 0.54	3.91 ± 0.52	0.009	0.00	0.970
Week 5	3.82 ± 0.38	3.90 ± 0.59	0.08	0.16	0.707
Week 6	3.61 ± 0.54	3.91 ± 0.45	0.30	0.60	0.190

$P < 0.05$

DISCUSSION

The main purpose of the study was to examine the effects of a 6-week supplemental RSA training vs. standard training alone on LnRMSSD in elite soccer players. The findings of the present study highlight no significant week to week differences in LnRMSSD, nor baseline – final measurement differences in EXP, opposed to CON. EXP exhibits increases in LnRMSSD over the first 5 weeks, after which a decrease in week 6 is observed. In general, CON shows increases in LnRMSSD in all weeks, except for week 3, where a trivial decline can be seen. Overall, RSA produces minor changes in LnRMSSD, irrespective of group assignment.

It has been well-documented that soccer has months of prolonged competition with strenuous activities, including the mixture of training with at least one match per week (11, 33). Although LnRMSSD is an effective tool to determine an individual's readiness and fatigue states (19), little evidence shows its practical application in prescribing a soccer training program, mainly because of the complex nature of soccer performance (39). Most previous studies examining the effects of RSA on LnRMSSD in male soccer players have been mostly conducted during a pre-season period (7, 16-18, 35, 36), while only a handful during the in-season period (9, 10, 13). As stated, a competitive season is characterized by a high workload of training and matches, and evidence suggests that positive effects of RSA on LnRMSSD may not be suitable during this period (42). The findings indicate that RSA has a nonsignificant impact on LnRMSSD during both pre-season (Std. diff. in means = -0.76 to 0.31) and competitive season (Std. diff. in means = -0.46 to 0.67) (19). Irrespective of soccer periods, the random effects model results obtained by a systematic review and meta-analysis of García-Ortega et al. (19) showed that RSA exhibited minor effects (Cohen $D = 0.14$) on LnRMSSD, which in line with our results. Although we found no significant changes, an interesting pattern of an LnRMSSD decline in the last week of intervention for EXP was shown. The decrease in HRV suggested a potential increase in fatigue or autonomic stress, which may indicate that soccer players in EXP became less resilient and struggled to challenge strenuous situations. Despite these changes, previous studies have shown that RSA has beneficial role on the cardiac autonomic responses, which have been associated with increases in VO_2max and with training load (42). However, the changes in VO_2max and training load in our sample were not significantly correlated with changes in LnRMSSD (data not shown).

In pre-season/off-season, soccer training is composed of aerobic and high-intensity soccer-specific exercises, which positively change the autonomous balance between sympathetic and parasympathetic systems, increasing the vagal modulation of heart rate and decreasing alertness produced by sympathetic activity (41). Also, these periods are characterized by higher aerobic volume and exercise intensity, compared to the competitive period, leading to greater LnRMSSD changes (7, 17). A chronological age seems to be a major contributing factor for intervention-induced changes of LnRMSSD (19). Larger LnRMSSD effect sizes have been observed in soccer players between the ages of 20 and 25 years (19), while the mean age of our sample was 18.5 years. More experienced soccer players tend to have higher vagal and lower sympathetic modulation, indicating better adaptations to the accumulated training and match loads (8, 9). Finally, male soccer players generally have higher sympathetic activity and lower vagal activity (11), which is more pronounced during the competition period, due to work overload and busy schedule between trainings and matches (42). This would imply that during the competitive season, soccer players do not have enough time to regenerate from previous high-intensity activities, which was presented in this study. Thus, it is not surprising that EXP group accumulated an extra fatigue following the additional RSA training, stimulating sympathetic system even more and preventing an optimal homeostasis between sympathetic and parasympathetic activity. However, the decline in the last week of intervention was not statistically significant from baseline LnRMSSD, although the Cohen d indicated small-to-moderate effects (0.30). This indicates that longer intervention duration may exhibit even larger declines in LnRMSSD, but such a hypothesis has yet to be investigated. A recent study by García-Ortega et al. (19) highlighted that the follow-up period ranged between one day to 6 months, where shorter periods did not lead to significant time changes in LnRMSSD (8, 9, 17, 18). Also, a large variability between the studies in terms of age, gender, session periods, the type of training, intervention duration, players' experience and the time of LnRMSSD measurement failed to support the general hypothesis that RSA had an impact on LnRMSSD (19).

Irrespective of previous findings, LnRMSSD has become an important physiological component of individuals' readiness and recovery after training-match loads. An easy-to-use and inexpensive tool can be used at individual and group level for personal development and comparison to other soccer players in regard to playing position and the training and match intensities during the season. Despite these advantages, this study has a few limitations. Indeed, the ability to examine the effects of the additional RSA training on LnRMSSD is needed, the follow-up period was short, disabling soccer players to acclimate to external work conditions. Second, the measurement protocol was done during the competitive period, and the lack of significant changes might have been due to week-to-week workload intensity. Third, our sample was recruited from one football club, limiting the generalizability to other soccer players from different 1st league football clubs. Finally, we were unable to measure the level of motivation during the follow-up, which could impact on the findings. Specifically, it was expected that certain individuals within EXP would put more effort into RSA performance, compared to their peers. However, the one sample Student *t*-test showed no significant within-group differences in LnRMSSD at baseline and during each week, concluding similar changes and very small variations between soccer players. Based on aforementioned limitations, future research should focus on investigating the effects of RSA on LnRMSSD during longer follow-up period and with soccer players from different clubs in pre-season, in-season and post-season time periods, to obtain more generalizable findings.

CONCLUSION

In summary, this study shows that the additional RSA training over a 6-week follow-up period had no significant effects on LnRMSSD during competitive season in soccer players. However, the tendency of a LnRMSSD decline in week 6 for EXP may indicate that supplemental training consisted of sprints can accumulate fatigue and is able to impair parasympathetic activity for total recovery. Nevertheless, this study confirms and adds to the existing body of literature (19) that RSA training appears to have a small, non-significant impact on HRV during the competitive season.

References

1. Archiza B, Andaku DK, Beltrame T, Libardi CA, Borghi-Silva A. The relationship between repeated-sprint ability, aerobic capacity, and oxygen uptake recovery kinetics in female soccer athletes. J Hum Kinet. 2020; 75: 115-26.
2. Baldi M, DA Silva JF, Buzzachera CF, Castagna C, Guglielmo LG. Repeated sprint ability in soccer players: associations with physiological and neuromuscular factors. J Sports Med Phys Fitness. 2017; 57(1-2): 26-32.
3. Bangsbo J. Physiological demands of football. Sports Sci Exch. 2014; 27: 1–6.
4. Bishop D, Girard O, Mendez-Villanueva A. Repeated-sprint ability - part II: recommendations for training. Sports Med. 2011; 41(9): 741-56.
5. Bishop D, Edge J. Determinants of repeated-sprint ability in females matched for single-sprint performance. Eur J Appl Physiol. 2006; 97(4): 373-9.
6. Bogdanis GC, Nevill ME, Boobis LH, Lakomy HK. Contribution of phosphocreatine and aerobic metabolism to energy supply during repeated sprint exercise. J Appl Physiol (1985). 1996; 80(3): 876-84.
7. Boullosa DA, Tuimil JL, Leicht AS, Crespo-Salgado JJ. Parasympathetic modulation and running performance in distance runners. J Strength Cond Res. 2009; 23(2): 626-31.
8. Buchheit M, Mendez-Villanueva A, Delhomel G, Brughelli M, Ahmaidi S. Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training. J Strength Cond Res. 2010a; 24(10): 2715-22.
9. Buchheit M, Mendez-Villanueva A, Quod MJ, Poulos N, Bourdon P. Determinants of the variability of heart rate measures during a competitive period in young soccer players. Eur J Appl Physiol. 2010b; 109(5): 869-78.
10. Buchheit M, Simpson MB, al Haddad H, et al. Monitoring changes in physical performance with heart rate measures in young soccer players. Eur J Appl Physiol. 2012; 112: 711–23.
11. Carling C, McCall A, Le Gall F, et al. What is the extent of exposure to periods of match congestion in professional soccer players? J Sports Sci. 2015; 33: 2116–24.
12. Chaouachi A, Manzi V, Wong del P, et al. Intermittent endurance and repeated sprint ability in soccer players. J Strength Cond Res. 2010; 24(10): 2663-9.
13. Chrismas BCR, Taylor L, Thornton HR, et al. External training loads and smartphone-derived heart rate variability indicate readiness to train in elite soccer. Int J Perform Anal Sport. 2019; 19: 143–52.
14. da Silva JF, Guglielmo LG, Bishop D. Relationship between different measures of aerobic fitness and repeated-sprint ability in elite soccer players. J Strength Cond Res. 2010; 24(8): 2115-21.
15. Dong JG. The role of heart rate variability in sports physiology. Exp Ther Med. 2016; 11(5): 1531-6.
16. Esco M, Flatt A, Nakamura F. Initial weekly HRV response is related to the prospective change in VO2max in female soccer players. Int J Sports Med. 2016; 37: 436-41.
17. Figueiredo DH, Figueiredo DH, Moreira A, et al. Effect of overload and tapering on individual heart rate variability, stress tolerance, and intermittent running performance in soccer players during a preseason. J Strength Cond Res. 2019; 33: 1222–31.
18. Flatt AA, Esco MR, Nakamura FY. Individual heart rate variability responses to preseason training in high level female soccer players. J Strength Cond Res. 2017; 31(2): 531-8.
19. García-Ortega D, Granero-Gallegos A, Carrasco-Poyatos M. Effects of training on the heart rate variability of competitive soccer players: A systematic review with meta-analysis. Int J Sports Sci Coach. 2023; 18(5): 1754-67.
20. Gharbi Z, Dardouri W, Haj-Sassi R, Castagna C, Chamari K, Souissi N. Effect of the number of sprint repetitions on the variation of blood lactate concentration in repeated sprint sessions. Biol Sport. 2014; 31(2): 151-6.
21. Girard O, Mendez-Villanueva A, Bishop D. Repeated-sprint ability - part I: factors contributing to fatigue. Sports Med. 2011; 41(8): 673-94.
22. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009; 41(1): 3-13.
23. Impellizzeri FM, Rampinini E, Marcora SM. Physiological assessment of aerobic training in soccer. J Sports Sci. 2005; 23(6): 583-92.
24. Impellizzeri FM, Rampinini E, Castagna C, et al. Validity of a repeated-sprint test for football. Int J Sports Med. 2008; 29(11): 899-905.
25. Internet page: https://www.randomizer.org/ assessed on the 14th of April 2025.
26. Kaplan T. Examination of repeated sprinting ability and fatigue index of soccer players according to their positions. J Strength Cond Res. 2010; 24(6): 1495-501.
27. Klarić Z, Hopovac A. The influence of training on autonomic nervous system cardiac modulation. In: Zvonar M, Sajdlova Z, editors. Proceedings of the 11th international conference of kinanthropology. 2017 Nov 29 – Dec 01; Brno, Czech Republic; 2017. p. 783-792.
28. Meckel Y, Doron O, Eliakim E, Eliakim A. Seasonal variations in physical fitness and performance indices of elite soccer players. Sports (Basel). 2018; 6(1): 14.
29. Mirto M, Filipas L, Altini M, Codella R, Meloni A. Heart rate variability in professional and semiprofessional soccer: A scoping review. Scand J Med Sci Sports. 2024; 34(6): e14673.
30. Moalla W. Physical and anthropometric changes during pre- and in-season in professional soccer players. J Sports Med Phys Fitness. 2016; 56(10): 1163-70.

31. Morgans R, Rhodes D, Teixeira J, et al. Quantification of training load across two competitive seasons in elite senior and youth male soccer players from an English Premiership club. Biol Sport. 2023; 40(4): 1197-205.
32. Moya-Ramon M, Mateo-March M, Peña-González I, Zabala M, Javaloyes A. Validity and reliability of different smartphones applications to measure HRV during short and ultra-short measurements in elite athletes. Comput Methods Programs Biomed. 2022; 217: 106696.
33. Mujika I, Halson S, Burke LM, et al. An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. Int J Sports Physiol Perform. 2018; 13: 538–61.
34. Nedrehagen ES, Saeterbakken AH. The effects of in-season repeated sprint training compared to regular aoccer training. J Hum Kinet. 2015; 49: 237-44.
35. Nobari H, Ramachandran AK, Brito JP, Oliveira R. Quantification of pre-season and in-season training intensity across an entire competitive season of Asian professional soccer players. Healthcare (Basel). 2022; 10(8): 1367.
36. Oliveira RS, Leicht AS, Bishop D, Barbero-Álvarez JC, Nakamura FY. Seasonal changes in physical performance and heart rate variability in high level futsal players. Int J Sports Med. 2013; 34(5): 424-30.
37. Plews DJ, Laursen PB, Kilding AE, Buchheit M. Heart rate variability in elite triathletes, is variation in variability the key to effective training? A case comparison. Eur J Appl Physiol. 2012; 112(11): 3729-41.
38. Rampinini E, Sassi A, Morelli A, Mazzoni S, Fanchini M, Coutts AJ. Repeated-sprint ability in professional and amateur soccer players. Appl Physiol Nutr Metab. 2009; 34(6): 1048-54.
39. Rave G, Fortrat JO, Dawson B, et al. Heart rate recovery and heart rate variability: use and relevance in European professional soccer. Int J Perform Anal Sport. 2018; 18: 168–83.
40. Sánchez-Sánchez J, Botella J, Felipe Hernández JL, et al. Heart rate variability and physical demands of in-season youth elite soccer players. Int J Environ Res Public Health. 2021; 18(4): 1391.
41. Seiler S, Haugen O, Kuffel E. Autonomic recovery after exercise in trained athletes: intensity and duration effects. Med Sci Sports Exerc. 2007; 39: 66–1373.
42. Soares-Caldeira LF, de Souza EA, de Freitas VH, de Moraes SM, Leicht AS, Nakamura FY. Effects of additional repeated sprint training during preseason on performance, heart rate variability, and stress symptoms in futsal players: a randomized controlled trial. J Strength Cond Res. 2014; 28(10): 2815-26.
43. Stanley J, Peake JM, Buchheit M. Cardiac parasympathetic reactivation following exercise: implications for training prescription. Sports Med. 2013; 43(12): 1259-77.
44. Varley MC, Aughey RJ. Acceleration profiles in elite Australian soccer. Int J Sports Med. 2013; 34(1): 34-9.
45. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013; 310(20): 2191-4.