Journal of Physical Education and Sport ® (JPES), Vol. 22 (issue 10), Art 321, pp. 2530 - 2538, October 2022
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Effectiveness of repeated sprint ability (RSA) development in youth soccer players

MAREK TVRDÝ[1], MIROSLAV HOLIENKA[2], MATEJ BABIC[3]
[1,2]Department of Sports Games, Faculty of Physical Education and Sports, Comenius University in Bratislava, SLOVAKIA
[3]Department of Physical Education and Sports, Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava, SLOVAKIA

Published online: October 31, 2022
(Accepted for publication October 15, 2022)
DOI:10.7752/jpes.2022.10321

Abstract
This research aimed at finding out the effectiveness of a 6-week training program aimed at developing repeated sprint ability (RSA) of U19 soccer players. The experimental group consisted of elite youth soccer players (n = 14) in the club of the Slovak First league U19. Three different tests were used to obtain data: Bangsbo sprint test, 10-m sprint and 20-m sprint test. Players completed a 6-week control period, with a predominance of specific stimuli without targeted RSA development through repeated sprints. Subsequently, they completed a 6-week experimental period which was complemented by an experimental factor focused on developing of RSA using repeated 20 m sprints. After the control period, players worsened in RSA parameters: RSA_{mean} (p = 0.02, r = 0.61) RSA_{best} (p = 0.03, r = 0.59) RSA_{worst} (p = 0.07, r = 0.21) RSA_{FI} (p = 0.29, r = 0.07). After the experimental period, the players improved their performance in the parameters of RSA: RSA_{mean} (p = 0.001, r = 0.80) RSA_{best} (p = 0.001, r = 0.82) RSA_{worst} (p = 0.001, r = 0.78) RSA_{FI} (p = 0.12, r = 0.31). There was an improvement in the acceleration speed in the 10-m sprint test (p = 0.02, r = 0.60) and in the 20-m sprint test (p = 0.002, r = 0.63). According to the results, the effectiveness of the speed-endurance training program was determined. We proved the necessity of using non-specific stimuli in developing repeated sprint ability in soccer players.
Key words: **soccer training, testing, repeated sprint ability, physical performance, sport performance**

Introduction

In the past, soccer was considered as an endurance sport. However, the intensification of training and competition load, as the most significant development trend, has diametrically changed the view on loads in soccer. Soccer differs from endurance sports as well as speed-strength sports with its structure of match load. The new functional-motor ability characteristic for the load in soccer results from a combination of speed-strength and speed-endurance abilities (Holienka 2005). Several authors (Holienka 2005; Bravo et al. 2008; Barbero-Álvarez et al. 2013; Andrzejewski et al. 2015; Sweeting et al. 2017) state that the main requirement for a player in a match is currently the ability to repeat short-term high-intensity physical activity without reducing the intensity, which alternates with medium to low-intensity physical activities throughout the match.

Several authors (Spencer et al. 2006; Mujika et al. 2009; Girard et al. 2011; Serpiello et al. 2011; Jones et al. 2013; Bujalance-Moreno et al. 2017) confirm the importance of this fitness requirement as one of the limiting performance factors for all sports games and call this ability the repeated sprint ability (RSA). Nowadays, the intensification is most often manifested by an increase in the total running volume at high to maximum intensity in the match, which has been empirically demonstrated in several research studies (Barnes et al. 2014; Bush et al. 2015; Bradley et al. 2016; Bush et al. 2017; Pons et al. 2021). At present, the volume of high-intensity runs (19.8-25.1 km/h) ranges from 335 to 596 m per match. The volume of sprints (> 25.1 km/h) in a match ranges from 96 to 295 m per match (Pons et al. 2019; Modrič et al. 2020). Bradley et al. (2014) or Cetin & Kocak (2022) too, pointed to a significant difference in the total volume of repeated sprints regarding player´s position. The authors of these studies recorded significantly higher values for side players and forwards compared to middle defenders and middle players. The importance of speed capacity has also been demonstrated in research by Bradley et al. (2014), who did not find a significant difference in the total running volume above 25 km/h compared to the 1st and 2nd half in the UEFA Champions League matches, which shows the high RSA level of top-level players. The ratio of high - intensity runs to the achieved total distance is 1-10% (Stolen et al. 2005; Buchheit et al. 2010a), of which up to 85% are runs with direction changes (Caldbeck 2020).

Trapattoni (1999) and Abrantes et al. (2004) assume that due to the unpredictability of the game, the increased volume of sprints can affect the number of balls gained, goals scored and the final result of the match too. The level of RSA is significantly affected by fatigue, which develops noticeably after the first sprint

Corresponding Author: MATEJ BABIC, E-mail: matej.babic@stuba.sk

(Mendez-Villanueva et al. 2006). Girard et al. (2011) state that fatigue can be caused by various factors, from the generation of inadequate motor command in the motor cortex (CNS factors) to the accumulation of muscle metabolites (muscular factors), and besides that they report that there is no single global mechanism responsible for fatigue. If the player wants to complete a larger number of high-intensity activities in the match, or to run a longer distance at high to maximum intensity, it is necessary to adapt his training load to the requirements of current soccer´s repeated sprint ability.

At present, small-sided games are often used to develop game fitness in soccer. However, several studies (Hill-Haas et al. 2006; Gábriš 2012; Gábriš 2015; Eniseler et al. 2017; Kargarfard et al. 2020; Negra et al. 2020; Akdogan et al. 2021; Aloui et al. 2021; Koral et al. 2021) pointed to the insufficient stimulus of specific means (small-sided games) for the development of RSA in soccer. Impellizzeri et al. (2008) and Bishop et al. (2011) therefore recommend using in the training process a combination of specific means (small-sided games) and non-specific means (repeated short sprints). The benefits of high-intensity anaerobic training (a load interval of 15 to 90 seconds) for the development of several types of fitness skills such as anaerobic performance, anaerobic capacity, RSA and aerobic performance have been discovered already in the past (Houston et al. 1977; Sharp et al. 1986; Jacobs et al. 1987; Bell et al. 1988). The disadvantage of this kind of load is the need for a long rest interval, which ensures further full-featured repetitions (above 90% 1RM). However, according to Dawson et al. (1998), even a long rest interval does not guarantee that the required intensity will be maintained during further several repetitions. Most important fact is that a long-lasting high-intensity load is not typical for sports games, and therefore for soccer as well (Holienka 2005; Ivanka 2015). Turner & Stewart (2013), Zagatto et al. (2017), Lopes-Silva et al. (2019) or Baranovič & Zemková (2021) also, emphasize the importance of adapting the training protocol focused on the development of RSA, the temporal and mechanical nature of movement in the match. Brahim et al. (2016) also point to the need to individualize the RSA training protocol with respect to the player´s position.

The most often complete the players in a match sprints lasting from 2 to 4 seconds (10 to 30 m distance) with a rest interval of 10 to 30 seconds. The total number of sprints ranges from 20 to 50 sprints per match (Dawson 2012; Varley et al. 2014; Ingebrigtsen et al. 2015; Lopes-Silva et al. 2016; Malone et al. 2017). Ivanka (2015) states that the rest interval between sprints is 30 to 90 seconds. Ulupınar et. al. (2021) compared two RSA training guidelines (10 x 40 m - rest interval: 30sec/20 x 20 m - rest interval: 15sec). They recorded higher engagement of the ATP-CP and glycolytic system in the 10 x 40 m training. This was confirmed also by the higher lactate blood concentration in the 10 x 40 m group, what means that training with the rest interval of 30sec might be more efficient for the RSA development when compared to the 20 x 20 m training. According to Balsom et al. (1992) the advantage of exercises with a short load (up to 10 sec) is that we can reach the maximum, or in other words the submaximal intensity in individual sprint repetitions with a relatively short rest interval (30 to 120 sec). Dawson et al. (1998) confirm that with optimal dosing of the load and rest interval, it is possible to perform a relatively large number of repetitions (15 and more) at almost maximum intensity.

Materials and Methods

Participants

The experimental group consisted of elite youth soccer players (n = 14; age = 18.2 ±0.54 years, body height = 181.14 ±5.27 cm, body weight = 74.59 ±5.53 kg) in the club of the Slovak first league U19. Goalkeepers were not involved in this experiment.

Procedures

The aim of the research was to determine the effectiveness of a 6-week training program aimed at developing the level of repeated sprint ability (RSA) using non-specific stimuli. We determined the dynamics of changes in the RSA level on the basis of two RSA development strategies, which means we used only specific stimuli and a combination of specific and non-specific stimuli. We assumed that the use of solely specific stimuli (control period (t_0-t_1)) would not lead to an improvement in the RSA level. On the contrary, we assumed that the combination of specific and non-specific stimuli (experimental period (t_1-t_2)) would provide a sufficient stimulus to improve the RSA level.

Table 1. Special training indicators during the control and experimental period

Special training indicators	Number [min / %]		Difference
	Control period	Experimental period	
Specific (game) training	2240 / 80 %	2050 / 70%	-190
Non-specific (conditioning) training	560 / 20 %	850 / 30 %	290
Speed	140	140	0
Strenght a power	280	270	-10
Endurance	0	300	300
Coordination	140	140	0

The experimental factor focused on the development of RSA comprised repeated 20 m sprints at submaximal intensity with a rest interval of 25 seconds. The experimental factor was applied twice a week immediately after the warm-up. The total number of training sessions was 12. In the 1. – 6. training session we applied linear sprints. As part of the load periodization in the experimental period, we did not increase only the volume of intensive activity, but also the physical intensity of runs in the 7. - 12. training session by adding one change of direction by 90 (7. - 9. training session), or 180 degrees (10. – 12. training session). The volume of sprints in one training session was 600 to 720 m. Only players who completed at least 10 RSA training sessions were involved in the evaluation of this experiment.

Table 2. Volume characteristic of experimental factor (RSA)

Week	Training session	Distance [m]	Change of direction [°]	Sets	Number of repetition	Distance per session [m]	Distance per week [m]	Recovery between repetitions [s]	Recovery between sets [s]	Intensity
1.	1.	20	-	3	10	600	1200	25	240	submaxima
	2.					600				
2.	3.				11	660	1320			
	4.					660				
3.	5.				12	720	1440			
	6.					720				
4.	7.		90		10	600	1200			
	8.					600				
5.	9.				11	660	1320			
	10.		180			660				
6.	11.				12	720	1440			
	12.					720				

Table 3. Volume characteristics of the control and experimental period in terms of endurance training

Endurance training	Control period	Experimental period	Difference
Repeated sprint ability [m]			
RSA (20 m distance)	0	7940	7940

Besides the dynamics of changes in the RSA level, we also monitored changes in the acceleration speed level during both observed periods. We used three standardized tests to determine the level and dynamics of changes in the monitored fitness skills:

- Bangsbo sprint test (BST test) [s],
- 10-m sprint test [s],
- 20-m sprint test [s].

Bangsbo sprint test (BST test)

Subjects started the test from a standing position 0.5 m behind the starting photocell (time zero) and sprinted a total distance of 34.2 m involving a right or left swing after the first 10 m, then continued the sprint to the finish line where another photocell was placed (finish time). Subjects were asked to perform a 25 s active recovery consisting of jogging back to the starting line (Figure 1.). Verbal feedback was provided to the subject during the recovery run every 10 and 20 sec so the subject can be ready for the next run on time. The test leader said the word "ready" at approximately the 23rd second of the recovery time, and at the 25th second the test leader said the word "go". The procedure continued until the subject completed seven sprints (Bangsbo 1994). In this test we monitored four parameters: average time of all runs (RSA_{mean}), fatigue index, (RSA_{FI}), average of the best times of one run (RSA_{best}) and average of the worst times of one run (RSA_{worst}). We measured with an accuracy of 0.01 sec. To determine the fatigue index we used this formula FI= Tmin – Tmax / Tmax x 100 [%] (Bangsbo & Mohr 2012).

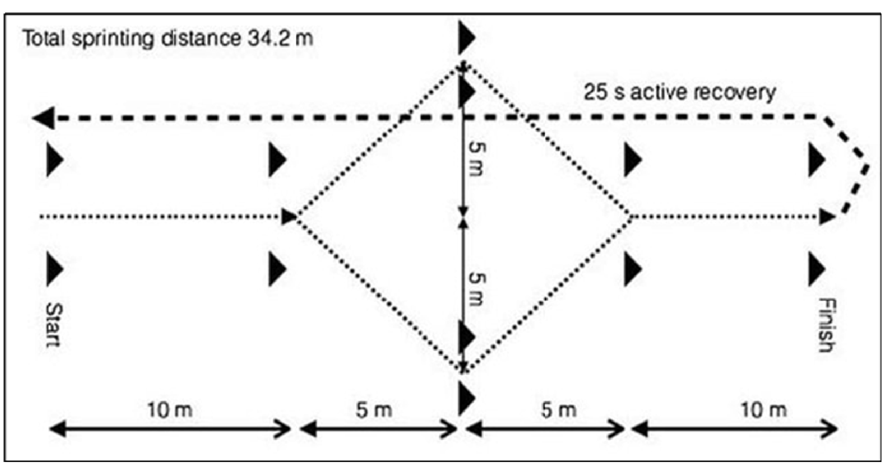

Figure 1. Bangsbo sprint test

10-m sprint test

Subjects started the test from a standing position 0.5 m behind the starting photocell (time zero) and sprinted a total distance of 10 m. Each participant performed two maximal trials with at least 3 minutes rest between them. To record sprint time, we used photocells and then the best scores were used for analysis. We measured with an accuracy of 0.01 sec.

20-m sprint test

Subjects started the test from a standing position 0.5 m behind the starting photocell (time zero) and sprinted a total distance of 20 m. Each participant performed two maximal trials with at least 3 minutes rest between them. To record sprint time, we used photocells and then the best scores were used for analysis. We measured with an accuracy of 0.01 sec.

Statistical analysis

The non-parametric Wilcoxon signed-rank test and Cohen´s „r" (effect size) was used for ranking the dependent variables for statistical significance of differences in measured times in the Bangsbo sprint test, 10-m sprint test and 20-m sprint test. The statistical significance level was set at $p < 0.05$. According to Cohen´s „*r*" we distinguish between: small effect ~ 0.1; medium effect ~ 0.3; large effect ~ 0.5 (Cohen 1988).

Results

Bangsbo sprint test

Table 4. RSA level changes in Bangsbo sprint test (RSA_{mean}).

Bangsbo sprint test (RSAmean)			
Measurement	t0	t1	t2
Mean [s]	6.31	6.39	6.21
p	-	0.02*	0.001**
Cohen´s *r*	-	0.61	0.80

We found out that after the control period (t_0-t_1) players significantly worsened in the RSAmean indicator (z = -2.04, p = 0.02, r = 0.61) After completing the experimental period (t_1-t_2), players improved significantly in this indicator (z = -3.01, p = 0.001, r = 0.80).

Table 5. RSA level changes in Bangsbo sprint test (RSA_{FI}).

Bangsbo sprint test (RSAFI)			
Measurement	t0	t1	t2
Mear. [%]	5.70	6.09	5.57
p	-	0.29	0.12
Cohen´s *r*	-	0.07	0.31

We found that the players worsened in the RSAFI indicator after completing the control period (t_0-t_1), but the deterioration was not significant (z = -0.53, p = 0.29, r = 0.07). After completing the experimental period (t_1-t_2), players improved in this indicator, but not significantly (z = -1.16, p = 0.12, r = 0.31).

Table 6. RSA level changes in Bangsbo sprint test (RSAbest).

Bangsbo sprint test (RSAbest)			
Measurement	t0	t1	t2
Mean [s]	6.13	6.18	6.03
p	-	0.03*	0.001**
Cohen´s *r*	-	0.59	0.82

We found that after completing the control period (t_0-t_1), players worsened significantly in the RSAbest indicator (z = -1.96, p = 0.03, r = 0.59). After completing the experimental period (t_1-t_2), the players improved significantly in this indicator (z = -3.08, p = 0.001, r = 0.82).

Table 7. RSA level changes in Bangsbo sprint test (RSAworst).

Bangsbo sprint test (RSAworst)			
Measurement	t0	t1	t2
Mean [s]	6.50	6.58	6.39
p	-	0.07	0.001**
Cohen´s *r*	-	0.21	0.78

We found that the players worsened in the RSAworst indicator after completing the control period (t_0-t_1), but the deterioration was not significant (z = -1.46, p = 0.07, r = 0.21). After completing the experimental period (t_1-t_2), players improved significantly in this indicator (z = -2.92, p = 0.001, r = 0.78).

10-m sprint test

Table 8. Acceleration speed level changes in 10-m sprint test.

10-m sprint test			
Measurement	t0	t1	t2
Mean [s]	1.67	1.66	1.64
p	-	0.38	0.02*
Cohen´s *r*	-	0.08	0.60

We found that the players improved in the 10-m sprint test after completing the control period (t_0-t_1), but the improvement was not significant ($z = -0.31$, $p = 0.38$, $r = 0.08$). After completing the experimental period (t_1-t_2), we noticed a significant improvement in the players during the 10-m sprint test ($z = -2.26$, $p = 0.02$, $r = 0.60$).

20-m sprint test

Table 9. Acceleration speed level changes in 20-m sprint test.

20-m sprint test			
Measurement	t0	t1	t2
Mean [s]	2.92	2.91	2.89
p	-	0.27	0.002**
Cohen´s *r*	-	0.04	0.63

We found that the players improved in the 20-m sprint test after completing the control period (t_0-t_1), but the improvement was not significant ($z = -0.59$, $p = 0.27$, $r = 0.04$). After completing the experimental period (t_1-t_2), we noticed a significant improvement in the players during the 20-m sprint test ($z = -2.90$, $p = 0.002$, $r = 0.63$).

Discussion

Our aim in our research was to verify the effectiveness of the development of repeated sprint ability (RSA) by two approaches - using specific stimuli and combination of specific stimuli and short repeated sprints.

After completing the control period, players recorded a deterioration in all monitored RSA indicators (RSA_{mean}, RSA_{FI}, RSA_{best}, RSA_{worst}). On the contrary, after completing the experimental period, players noticed an improvement in all RSA parameters (RSA_{mean}, RSA_{FI}, RSA_{best}, RSA_{worst}). According to the achieved results, we can state that despite some studies (Buchheit et al. 2009; Rodríguez-Fernández et al. 2016), which showed an improvement in RSA parameters after a specific training session, our research did not confirm that only a specific soccer load (control period) would provide a sufficient stimulus causing increase in the RSA level. Our results agree with the results of several authors (Hill-Haas et al. 2006; Gábriš 2012; Gábriš 2015; Eniseler et al. 2017; Kargarfard et al. 2020; Negra et al. 2020; Akdogan et al. 2021; Aloui et al. 2021; Koral et al. 2021), who also did not demonstrate the ability to develop RSA parameters using only specific soccer trainings.

On the contrary, we were able to prove a significant improvement in RSA after applying an experimental factor consisting of short repeated sprints. The only parameter in which we failed to prove the statistical significance of the improvement was the fatigue index (RSA_{FI}). Our results after the application of the experimental period confirm also the previous conclusions of various studies (Dawson et al. 1998; Mohr et al. 2007; Bravo et al. 2008; Schneiker & Bishop 2008; Buchheit et al. 2010b; Serpiello et al. 2011; Iaia et al. 2017; Rey et al. 2017; Aloui et al. 2021; Koral et al. 2021), which recorded significant increases in the level of RSA after the impact of the training program composed of repeated sprints. The interesting fact is that some studies (Dawson et al. 1998; Buchheit et al. 2008; Schneiker & Bishop 2008; Gábriš 2015; Rodríguez-Fernández et al. 2016) have shown not only an increase in the RSA level, but in the fatigue index in % as well. On the contrary, recent studies (Buchheit et al. 2008; Rey et al. 2017; Aloui et al. 2021) recorded a decrease in the fatigue index, while other RSA parameters improved. The increase in fatigue index while improving RSA is explained by Bishop et al. (2003); Yanagiya et al. (2003) or Mendez-Villanueva et al. (2008). They say that it is caused by increasing the initial performance (or more initial performances), which lead to a higher decrease in performance in later repetitions. We assume that this result was due to an increase in the aerobic endurance level (VO_{2max}, anaerobic threshold) by using specific means, which resulted in faster ATP resynthesis at rest intervals and a higher percentage of energy compensation by aerobic metabolism during repeated sprints. According to our results, the optimal strategy for the development of RSA in soccer is a combination of specific and non-specific stimuli in the training process, which is coincident with the results of other studies (Impellizzeri et al. 2008; Bishop et al. 2011).

Besides the dynamics of changes in the RSA level, we also monitored the impact on the level of acceleration speed. We recorded an improvement in both periods, while in the control period was this improvement not statistically significant. In terms of dosage, the speed program was the same in both periods.

The dosage in the game training was comparable. Thanks to this result we can assume that a significant improvement in the experimental period was supported, not only by the speed program, but also by experimental factor - submaximal repeated sprints. This statement is also supported by the results of studies by Buchheit et al. (2010c), Rey et al. (2017) or Aloui et al. (2021), in which there was an improvement in the acceleration speed after the application of short repeated sprints.

Conclusions

The ability to repeat high-intensity activities (RSA) with the least possible decrease in intensity throughout the match is currently becoming a limiting factor in the fitness of players. Although the relationship between the volume of high-intensity running and the successful outcome of the match has not yet been proved (indicating the high conditionality of technical and tactical level of players), a higher level of RSA creates a precondition for faster involvement of players and an increase in the number of players involved in offensive, or defensive, phase of the game. This creates an increased chance of scoring a goal or preventing it.

After the use of specific stimuli, we recorded a decrease in the level of RSA in all monitored indicators, while the decrease in the indicator RSA_{best} was significant ($p = 0.03$).

On the contrary, the combined approach provided a significant improvement in all RSA parameters, except RSAFI. Based on the measured results, we can confirm the high effectiveness of the experimental stimulus as well as high safety, as we did not notice any injuries caused during the application of the experimental stimulus.

The level of acceleration speed improved in both periods. In the experimental period, the improvement was significant ($p = 0.02$, $p = 0.002$). It was probably ensured by the application of repeated sprints. The same volume of speed and game training were used. Based on our results, we recommend to include in the training process of U19 soccer players a combination of specific stimuli (interval method) and short repeated sprints up to 20 m (submaximal intensity, rest interval – 25 sec), which ensures the development of RSA. The frequency should be two times in a weekly microcycle in pre-season and at least one time in the main season, so the level of RSA is maintained. At the same time, we recommend that the total volume of speed-endurance load within one training session should be in the range of 600 to 720 m.

Acknowledgments

This research was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences (no. 1/0089/20).

References

Abrantes, C., Macas, V., & Sampaio, J. (2004). Variation in football players' sprint test performance across different ages and levels of competition. *Journal of Sports Science and Medicine*, *3*(1), 44-49.
Akdogan, E., Yılmaz, I., Köklü, Y., Alemdaroglu, U., & Cerrah, A. O. (2021). The effect of isolated or combined small-sided games and speed endurance training on physical performance parameters in young soccer players. *Kinesiology*, *53*(1), 78-85.
Aloui, G., Souhail, H., Hayes, L. D., Bouhafs, E. G., Chelly, M. S., & Schwesig, R. (2021). The effects of loaded plyometrics and short sprints in U19 male soccer players in Tunisia. *Applied Sciences*, *11*(16), 7621.
Andrzejewski, M., Chmura, J., Pluta, B., & Konarski, J. M. (2015). Sprinting activities and distance covered by top level Europa league soccer players. *International Journal of Sports Science and Coaching*, *10*(1), 39-50.
Balsom, P. D., Seger, J. Y., Sjödin, B., & Ekblom, B. (1992). Maximal-intensity intermittent exercise: effect of recovery duration. *International Journal of Sports Medicine*, *13*(7), 528-533.
Bangsbo, J. (1994). *Fitness training in football*. HO+Storm: Bagsværd.
Bangsbo, J., & Mohr, M. (2012). *Fitness testing in football - fitness training in soccer II*. Bangsbo Sport: Espergaerde. ISBN 978-87-994880-0-1.
Baranovič, T., & Zemková, E. (2021). The relationship between the performance of soccer players on the curved sprint test, repeated sprint test, and change-of-direction speed test. *Applied Sciences*, *11*(12), 5355.
Barbero-Álvarez, J. C., Pedro, R. E., & Nakamura, F. Y. (2013). Validity of a repeated-sprint ability test in young soccer players. *Science and Sports*, *28*(5), 127-131.
Barnes, C., Archer, D. T., Hogg, B., Bush, M., & Bradley, P. (2014). The evolution of physical and technical performance parameters in the English Premier League. *International Journal of Sports Medicine*, *35*(13), 1095-1100.
Bell, G. J., & Wenger, H. A. (1988). The effect of one-legged sprint training on intramuscular pH and nonbicarbonate buffering capacity. *European Journal of Applied Physiology and Occupational Physiology*, *58*(1), 158-164.
Bishop, D., Lawrence, S., & Spencer, M. (2003). Predictors of repeated-sprint ability in elite female hockey players. *Journal of Science and Medicine in Sport*, *6*(2), 199-209.
Bishop, D., Girard, O., & Mendez-Villanueva, A. (2011). Repeated-sprint ability-Part II. *Sports Medicine*, *41*(9), 741-756.

Bradley, P. S., Dellal, A., Mohr, M., Castellano, J., & Wilkie, A. (2014). Gender differences in match performance characteristics of soccer players competing in the UEFA Champions League. *Human Movement Science*, *33*, 159-171.

Bradley, P. S., Archer, D. T., Hogg, B., Schuth, G., Bush, M., Carling, C., & Barnes, C. (2016). Tier-specific evolution of match performance characteristics in the English Premier League: it's getting tougher at the top. *Journal of Sports Sciences*, *34*(10), 980-987.

Brahim, M. B., Mohamed, A., & Shalfawi, S. A. (2016). The evaluation of soccer players performance on different repeated sprint tests: Training and testing implications. *Kinesiologia Slovenica, 22*(2). 49-63.

Bravo, D. F., Impellizzeri, F. M., Rampinini, E., Castagna, C., Bishop, D., & Wisloff, U. (2008). Sprint vs. interval training in football. *International Journal of Sports Medicine*, *29*(8), 668-674.

Buchheit, M., Millet, G. P., Parisy, A., Pourchez, S., Laursen, P. B., & Ahmaidi, S. (2008). Supramaximal training and postexercise parasympathetic reactivation in adolescents. *Medicine and Science in Sports and Exercise*, *40*(2), 362-371.

Buchheit, M., Laursen, P. B., Kuhnle, J., Ruch, D., Renaud, C., & Ahmaidi, S. (2009). Game-based training in young elite handball players. *International Journal of Sports Medicine*, *30*(4), 251-258.

Buchheit, M., Mendez-Villanueva, A., Simpson, B. M., & Bourdon, P. C. (2010a). Repeated-sprint sequences during youth soccer matches. *International Journal of Sports Medicine*, *31*(10), 709-716.

Buchheit, M., Mendez-Villanueva, A., Quod, M., Quesnel, T., & Ahmaidi, S. (2010b). Improving acceleration and repeated sprint ability in well-trained adolescent handball players: speed versus sprint interval training. *International Journal of Sports Physiology and Performance*, *5*(2). 152-164.

Buchheit, M., Mendez-Villanueva, A., Delhomel, G., Brughelli, M., & Ahmaidi, S. (2010c). Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training. *Journal of Strength and Conditioning Research*, *24*(10), 2715-2722.

Bujalance-Moreno, P., García-Pinillos, F., & Latorre-Román, P. Á. (2017). Effects of a small-sided game-based training program on repeated sprint and change of direction abilities in recreationally-trained soccer players. *Journal of Sports Medicine and Physical Fitness*, *58*(7-8), 1021-1028.

Bush, M., Barnes, C., Archer, D. T., Hogg, B., & Bradley, P. S. (2015). Evolution of match performance parameters for various playing positions in the English Premier League. *Human Movement Science*, *39*, 1-11.

Bush, M., Archer, D. T., Barnes, C., Hogg, B., & Bradley, P. S. (2017). Longitudinal match performance characteristics of UK and non-UK players in the English Premier League. *Science and Medicine in Football*, *1*(1), 2-9.

Caldbeck, P. (2020). *Contextual sprinting in Premier league football.* Dissertation thesis, John Moores University, Liverpool, UK.

Cetin, O., & Kocak, M. (2022). Repeated sprint ability of youth football players in the same age category according to playing position and competition level. *Montenegrin Journal of Sports Science and Medicine*, *11*(1), 59-63.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. 2nd edition. Lawrence Erblaum associates: Hillsdale.

Dawson, B., Fitzsimons, M., Green, S., Goodman, C., Carey, M., & Cole, K. (1998). Changes in performance, muscle metabfolites, enzymes and fibre types after short sprint training. *European Journal of Applied Physiology and Occupational Physiology*, *78*(2), 163-169.

Dawson, B. (2012). Repeated-sprint ability: Where are we?. *International Journal of Sports Physiology and Performance*, *7*(3), 285-289.

Eniseler, N., Şahan, Ç., Özcan, I., & Dinler, K. (2017). High-intensity small-sided games versus repeated sprint training in junior soccer players. *Journal of Human Kinetics*, *60*(1), 101-111.

Gábriš, C. (2012). *Adaptácia a odozva na rýchlostno-vytrvalostné zaťaženie futbalistu v prípravnom a súťažnom období*. [Adaptation and response to speed-endurance loading of a football in the training and competitive stage]. Diploma thesis, Comenius University in Bratislava.

Gábriš, C. (2015). *Rozvoj anaeróbnych schopností a ich vplyv na výkon futbalistov*. [Development of anaerobic abilities and their effect on performance of football players]. Dissertation thesis, Comenius University in Bratislava.

Girard, O., Mendez-Villanueva, A., & Bishop, D. (2011). Repeated-sprint ability-Part I. *Sports Medicine*, *41*(8), 673-694.

Hill-Haas, S. V., Coutts, A. J., Rowsell, G. J., & Dawson, B. T. (2009). Generic versus small-sided game training in soccer. *International Journal of Sports Medicine*, *30*(9), 636-642.

Holienka, M. (2005). *Kondičný tréning vo futbale*. PEEM: Bratislava, Slovakia. ISBN 80- 89197-21-3.

Houston, M. E., & Thomson, J. A. (1977). The response of endurance-adapted adults to intense anaerobic training. *European Journal of Applied Physiology and Occupational Physiology, 36*(3), 207-213.

Iaia, F. M., Fiorenza, M., Larghi, L., Alberti, G., Millet, G. P., & Girard, O. (2017). Short-or long-rest intervals during repeated-sprint training in soccer?. *PLoS One*, *12*(2), 1-15.

Impellizzeri, F. M., Rampinini, E., Castagna, C., Bishop, D., Bravo, D. F., Tibaudi, A., & Wisloff, U. (2008). Validity of a repeated-sprint test for football. *International Journal of Sports Medicine*, *29*(11), 899-905.

Ingebrigtsen, J., Dalen, T., Hjelde, G. H., Drust, B., & Wisløff, U. (2015). Acceleration and sprint profiles of a professional elite football team in match play. *European Journal of Sport Science*, *15*(2), 101-110.

Ivanka, M. (2015). *Funkčný futbalový fitnes tréning*. [Functional soccer fitness training]. Milan Ivanka: Bratislava, Slovakia. ISBN 978-99-9999-018-0.

Jacobs, I., Esbjörnsson, M. O. N. A., Sylven, C., Holm, I., & Jansson, E. (1987). Sprint training effects on muscle myoglobin, enzymes, fiber types, and blood lactate. *Medicine and Science in Sports and Exercise*, *19*(4), 368-374.

Jones, R. M., Cook, C. C., Kilduff, L. P., Milanović, Z., James, N., Sporiš, G., Fiorentini, B., Fiorentini, F., Turner, A., & Vučković, G. (2013). Relationship between repeated sprint ability and aerobic capacity in professional soccer players. *Scientific World Journal*, *1*, 1-5.

Kargarfard, M., Tajvand, S., Rabbani, A., Clemente, F. M., & Jalilvand, F. (2020). Effects of combined plyometric and speed training on change of direction, maximal speed, and repeated sprint ability in young soccer players. *Kinesiology*, *52*(1), 85-93.

Koral, J., Lloria Varella, J., Lazaro Romero, F., & Foschia, C. (2021). Effects of three preseason training programs on speed, change-of-direction, and endurance in recreationally trained soccer players. *Frontiers in Physiology, 12*, 1525.

Lopes-Silva, J. P., da Silva Santos, J. F., Abbiss, C. R., & Franchini, E. (2019). Measurement properties and feasibility of repeated sprint ability test: a systematic review. *Strength and Conditioning Journal*, *41*(6), 41-61.

Malone, S., Solan, B., & Collins, K. (2017). The running performance profile of elite Gaelic football match-play. *Journal of Strength and Conditioning Research*, *31*(1), 30-36.

Mendez-Villanueva, A., Hamer, P., & Bishop, D. (2008). Fatigue in repeated-sprint exercise is related to muscle power factors and reduced neuromuscular activity. *European Journal of Applied Physiology*, *103*(4), 411-419.

Modrič, T., Versič, S., & Sekulič, D. (2020). Playing position specifics of associations between running performance during the training and match in male soccer players. *Acta Gymnica*, *50*(2), 51-60.

Mohr, M., Krustrup, P., Nielsen, J. J., Nybo, L., Rasmussen, M. K., Juel, C., & Bangsbo, J. (2007). Effect of two different intense training regimens on skeletal muscle ion transport proteins and fatigue development. *American Journal of Physiology, Regulatory, Integrative and Comparative Physiology*, *292*(4), 1594-1602.

Mujika, I., Spencer, M., Santisteban, J., Goiriena, J. J., & Bishop, D. (2009). Age-related differences in repeated-sprint ability in highly trained youth football players. *Journal of Sports Sciences*, *27*(14), 1581-1590.

Negra, Y., Chaabene, H., Fernandez-Fernandez, J., Sammoud, S., Bouguezzi, R., Prieske, O., & Granacher, U. (2020). Short-term plyometric jump training improves repeated-sprint ability in prepuberal male soccer players. *Journal of Strength and Conditioning Research*, *34*(11), 3241-3249.

Pons, E., García-Calvo, T., Resta, R., Blanco, H., López del Campo, R., Díaz García, J., & Pulido, J. J. (2019). A comparison of a GPS device and a multi-camera video technology during official soccer matches: Agreement between systems. *PLoS One*, *14*(8), 1-12.

Pons, E., Ponce-Bordón, J. C., Díaz-García, J., López del Campo, R., Resta, R., Peirau, X., & García-Calvo, T. (2021). A longitudinal exploration of match running performance during a football match in the spanish La liga: A four-season study. *International Journal of Environmental Research and Public Health*, *18*(3), 1133.

Rey, E., Padrón-Cabo, A., & Fernández-Penedo, D. (2017). Effects of sprint training with and without weighted vest on speed and repeated sprint ability in male soccer players. *Journal of Strength and Conditioning Research*, *31*(10), 2659-2666.

Rodriguez-Fernandez, A., Sánchez, J. S., Rodriguez-Marroyo, J. A., Casamichana, D., & Villa, J. G. (2017). Effects of 5-week pre-season small-sided-game-based training on repeat sprint ability. *Journal of Sports Medicine and Physical Fitness*, *57*(5), 529-536.

Schneiker, K., & Bishop, D. (2008). The effect of high intensity interval training vs intermittent sprint training on physiological capacities importon for team sport performance. *Exercise and Sport Sciences Reviews, 7*(3), 62-68.

Serpiello, F. R., McKenna, M. J., Stepto, N. K., Bishop, D. J., & Aughey, R. J. (2011). Performance and physiological responses to repeated-sprint exercise: a novel multiple-set approach. *European Journal of Applied Physiology*, *111*(4), 669-678.

Sharp, R. L., Costill, D. L., Fink, W. J., & King, D. S. (1986). Effects of eight weeks of bicycle ergometer sprint training on human muscle buffer capacity. *International Journal of Sports Medicine*, *7*(1), 13-17.

Spencer, M., Fitzsimons, M., Dawson, B., Bishop, D., & Goodman, C. (2006). Reliability of a repeated-sprint test for field-hockey. *Journal of Science and Medicine in Sport*, *9*(1-2), 181-184.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer. *Sports Medicine*, *35*(6), 501-536.

Sweeting, A. J., Cormack, S. J., Morgan, S., & Aughey, R. J. (2017). When is a sprint a sprint? A review of the analysis of team-sport athlete activity profile. *Frontiers in Physiology*, *8*(432), 1-12.

Trapattoni, G. (1999). Coaching high performance soccer. Reedswain: Spring City. ISBN 978-1890946371.

Turner, A. N., & Stewart, P. F. (2013). Repeat sprint ability. *Strength & Conditioning Journal*, *35*(1), 37-41.

Ulupınar, S., Özbay, S., Gençoğlu, C., Franchini, E., Kishalı, N. F., & Ince, I. (2021). Effects of sprint distance and repetition number on energy system contributions in soccer players. *Journal of Exercise Science and Fitness*, *19*(3), 182-188.

Varley, M. C., Gabbett, T., & Aughey, R. J. (2014). Activity profiles of professional soccer, rugby league and Australian football match play. *Journal of Sports Sciences*, *32*(20), 1858-1866.

Yanagiya, T., Kanehisa, H., Kouzaki, M., Kawakami, Y., & Fukunaga, T. (2003). Effect of gender on mechanical power output during repeated bouts of maximal running in trained teenagers. *International Journal of Sports Medicine*, *24*(4), 304-310.

Zagatto, A. M., Ardigo, L. P., Barbieri, F. A., Milioni, F., Iacono, A. D., Camargo, B. H., & Padulo, J. (2017). Performance and metabolic demand of a new repeated-sprint ability test in basketball players: does the number of changes of direction matter?. *Journal of Strength and Conditioning Research*, *31*(9), 2438-2446.