

DIFFERENT ENDURANCE CHARACTERISTICS OF FEMALE AND MALE GERMAN SOCCER PLAYERS

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ABSTRACT: The aims of the present study were to assess gender differences regarding lactate threshold and intermittent shuttle run performance in female and male soccer players as well as to investigate the relationships between both endurance characteristics in both genders. Fourteen female (1st division) and thirteen male (4th division) soccer players completed an incremental test (IT) to determine running velocities at 2 and 4 mmol·l⁻¹ blood lactate (v2 and v4) and maximum velocity (v_{max}) as well as an interval shuttle run test (ISRT) to determine running distance. Based on v2 and v4 and their percentages in relation to v_{max}, three intensity zones were calculated: a low lactate zone (<v2), a lactate accommodation zone (v2 to v4), and a lactate accumulation zone (>v4). Female soccer players have a lower v4 (8.2%), v_{max} (11.3%) and ISRT distance (31.6%). No gender difference was found in v2. In contrast to males, ISRT distance correlates with v_{max} as well as with v2 and v4 in female soccer players. The intensity zones <v2 and >v4 differ between genders. The present study revealed that gender differences increase when the running performance is intermittent including change of directions. In both genders, different relationships between lactate threshold and intermittent shuttle run performance exist. During incremental testing, the running performances of female and male players reflect different distributions of aerobic and anaerobic metabolic pathways. The revealed gender differences should be considered for soccer endurance training.

KEY WORDS: aerobic, anaerobic, gender, interval shuttle run test, lactate threshold

INTRODUCTION

Endurance in soccer is characterized as high-intensity intermittent running performance [4,8] and is represented by the physical amount of work carried out throughout a match [11]. During matches, female and male soccer players cover a similar total running distance but differ regarding their performed high-intensity running activities [5, 23,24].

Various field endurance tests such as incremental exercise tests and intermittent shuttle run tests are currently used to evaluate training status and training adaptations, as well as to predict running performance during matches in soccer players [16,31].

Incremental exercise tests obtained parameters which yield aerobic endurance performance parameters (e.g., different lactate thresholds and maximum running velocity) [9,14,22,30,31]. Lactate thresholds are commonly used as a sensitive indicator of changes in training status in professional soccer players [35]. Furthermore, it has been shown that the lactate threshold correlates significantly with the total running distance during a match in both genders (females: $r=0.64$ $P=0.02$; males: $r=0.58$ $P<0.05$) but only with high-intensity running distances in female soccer players (females:

$r=0.83$ $P<0.001$; males: $r=0.26$ $P>0.05$) [1,16]. These correlations show that the lactate threshold contributes to the running performance during matches in both genders differently.

However, for a more soccer-specific assessment of endurance performance, field tests such as intermittent shuttle run tests were developed [15,20]. In these tests the covered running distance represents players' intermittent shuttle run performance. Considering that intermittent shuttle run performance evaluates both aerobic and anaerobic energy metabolism [19], it is reasonable that intermittent shuttle run performance correlates with the total running distance (females: $r=0.56$ $P=0.038$; males: $r=0.53$ $P<0.05$) and high-intensity running distance (females: $r=0.76$ $P=0.002$; males: $r=0.71$ $P<0.05$) during soccer matches in both genders [2,15,16].

Previous research has revealed no significant correlation between lactate threshold and intermittent shuttle run performance in professional male soccer players ($r=0.28$ $P>0.05$) [12]. In contrast, it has been shown that a correlation exists between lactate threshold and intermittent shuttle run performance in elite female soccer players ($r=0.73$ $P=0.003$) [16]. Thus, the results of the previous stud-

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ies indicate that the lactate threshold contributes to intermittent shuttle run performance in both genders differently.

To our knowledge, no previous study has assessed gender differences in lactate threshold and intermittent shuttle run performance in female and male soccer players. Furthermore, no study has investigated the relationships between both endurance characteristics in both genders. Since there is a rapidly growing number of female soccer players, it is interesting to study gender differences from this perspective as well.

The aims of the present study were to assess gender differences regarding lactate threshold and intermittent shuttle run performance in female and male soccer players as well as to investigate the relationships between both endurance characteristics in both genders.

MATERIALS AND METHODS

Participants. Fourteen female (1st division) and thirteen male (4th division) outfield soccer players participated in this study. These divisions were compared because the training volume is comparable (i.e., 5 times per week for 2 h). Both teams were recruited at the end of the first quarter of the season. All players were free from injury and illness. Table I shows the anthropometric characteristics of all players. The players were informed about the procedures and potential risks of this study before they gave their consent to participate. The players were familiar with all testing procedures as part of their regular performance assessment programme and were asked to keep their eating and drinking habits constant during the test period. The test procedures were approved by the ethics committee of the University of Wuppertal and were in accordance with the Declaration of Helsinki.

Experimental design

All players completed the following tests within one week: 1) an incremental test to determine two lactate thresholds and 2) an interval shuttle run test (ISRT) to determine the intermittent shuttle run performance. All tests were performed under nearly the same weather conditions (10 to 17°C; 62 to 77% humidity).

Throughout all tests, heart rate was measured at two-second intervals (Suunto t6, Vantaa, Finland) until 60 seconds of recovery and the maximum heart rates (HR_{max}) were determined.

Incremental test

The incremental test was performed on a dry 400 m outdoor all-weather running track with running shoes as reported previously [12]. The track was marked every 50 m with pylons and an acoustic signal was used to control the running speed. The initial running speed was 8.64 km · h⁻¹ for females and 10.08 km · h⁻¹ for males. The running speed increased every 5 min by 1.44 km · h⁻¹ until physical exhaustion occurred. The test was terminated if a player could not follow the given velocity. During a 30 s break after each stage as well as immediately after exhaustion, 20 µl of capillary blood was sampled from the ear lobe. The lactate concentrations

were analysed with an automated amperometric-enzymatic analyser (EKF Biosen C_line Sport, Magdeburg, Germany). The criteria for exhaustion were the following: 1) a minimum of 95% of predicted HR_{max} (220-age) or 2) a maximum capillary blood lactate concentration higher than 8 mmol · l⁻¹ [33]. The lactate curves were exponentially fitted and the running velocities at 2 and 4 mmol · l⁻¹ (v_2 and v_4) were calculated by linear interpolation. The reliability of v_2 and v_4 has been previously reported [34]. The maximum running velocity (v_{max}) was also assessed. Based on v_2 and v_4 and their percentages in relation to v_{max} , three intensity zones were calculated: a low lactate zone (< v_2), a lactate accommodation zone (where blood lactate concentration is elevated but production and clearance are in equilibrium) (v_2 to v_4), and a lactate accumulation zone, where blood lactate production exceeds clearance (> v_4) [3,29].

Interval shuttle run test

The ISRT was performed outdoors on a dry soccer field with soccer shoes as reported previously [20]. The players ran intermittent shuttles of 20 m. The running speed was controlled with acoustic signals. The initial speed was set to 10 km · h⁻¹ and increased every 90 s for 1 km · h⁻¹. The 90 s periods were divided into two 45 s periods. During the 45 s periods, the players ran for 30 s and walked for 15 s. At the end of the 13 km · h⁻¹ period, the increment was set to 0.5 km · h⁻¹ until physical exhaustion occurred. The test was terminated if a player could not follow the velocity during two consecutive shuttles. To quantify exhaustion, the players should reach a minimum of 95% of their predicted HR_{max} (220-age). The number of completed shuttles was multiplied by 20 m, representing the players' intermittent shuttle run performance. The reliability of the ISRT has been reported previously [18].

Statistical analysis

Descriptive data (mean ± sd) were calculated for all variables after checking for normality with a Kolmogorov-Smirnov test. No further transformation was required. Gender differences were analysed applying an independent two-sample t-test. The magnitudes of all gender differences were evaluated as eta squared [27]. The differences in maximum and recovery heart rates between the two endurance tests were calculated with a paired sample t-test. Additionally, magnitudes were expressed as eta squared as well [27]. The thresholds for small, moderate, and large effects were 0.01, 0.06, and 0.14, respectively [7]. Pearson product-moment correlation coefficients were used to determine the relationships between v_2 , v_4 , maximum velocity and ISRT distance. A level of $P < 0.05$ was set for statistical significance. For all statistical calculations SPSS Statistics 19 (IBM, New York, USA) was employed.

RESULTS

The mean and standard deviation values of all assessed variables are summarized in Table I.

TABLE 1. ANTHROPOMETRIC AND ENDURANCE CHARACTERISTICS OF FEMALE AND MALE SOCCER PLAYERS

Test	Parameter	Females [n=14]	Males [n=13]	P	Eta ²
Anthropometric characteristics	Age [years]	21.4 ± 4.6	22.8 ± 2.9	0.325	.039
	Body height [cm]	167 ± 5	181 ± 6	<0.001	.663
	Body mass [kg]	59.5 ± 5.4	76.8 ± 6.9	<0.001	.683
	Body mass index [kg·m ⁻²]	21.4 ± 1.4	23.4 ± 1.5	0.001	.347
Incremental test	Maximum heart rate [beats·min ⁻¹]	184 ± 7	188 ± 7	0.130	.089
	60 s heart rate recovery [beats·min ⁻¹]	33 ± 13	37 ± 10	0.494	.019
	Maximum blood lactate concentration [mmol·l ⁻¹]	8.3 ± 1.9	9.7 ± 2.6	0.109	.099
	Running velocity at 2 mmol·l ⁻¹ blood lactate (v2) [km·h ⁻¹]	11.9 ± 1.32	12.6 ± 0.94	0.138	.086
	Running velocity at 4 mmol·l ⁻¹ blood lactate (v4) [km·h ⁻¹]	13.4 ± 1.11	14.6 ± 0.67	0.003	.300
	Maximum running velocity [km·h ⁻¹]	14.9 ± 0.92	16.8 ± 0.76	<0.001	.586
	Intensity zone < v2 [%]	80.2 ± 5.6	75.1 ± 4.6	0.016	.209
	Intensity zone v2 to v4 [%]	9.9 ± 2.7	11.6 ± 2.8	0.106	.101
Interval shuttle run test	Intensity zone > v4 [%]	9.9 ± 3.9	13.2 ± 3.7	0.032	.170
	Running distance [m]	1536 ± 301	2245 ± 247	<0.001	.639
	Maximum heart rate [beats·min ⁻¹]	190 ± 6	192 ± 6	0.470	.021
	60 s heart rate recovery [beats·min ⁻¹]	30 ± 8.4	33 ± 7.5	0.360	.034

No differences regarding age were found between female and male players ($P=0.325$). The male players were taller ($P<0.001$) and had a higher body mass ($P<0.001$) and body mass index ($P=0.001$) than female players.

Gender differences were found in the incremental test regarding v4 ($P=0.003$) and maximum velocity ($P<0.001$), being higher in male compared to female players. There were no gender differences in v2, maximum heart rate, 60 s heart rate recovery and maximum blood lactate concentration (all $P>0.05$). Additionally, the intensity zones <v2 ($P=0.016$) and >v4 ($P=0.032$) differed between genders (Figure 1).

During the ISRT, male soccer players covered a greater running distance compared to female players ($P<0.001$). No gender differences were evident in maximum heart rate and the heart rate after 60 s of recovery (both $P>0.05$).

In both genders, differences between the incremental test and the ISRT existed concerning maximum heart rates (females: $P<0.001$ eta²=0.80; males: $P<0.019$ eta²=0.38) but not 60 s heart rate recovery (both $P>0.05$).

The results of the correlation analysis are summarized in Table 2. In female soccer players, the maximum velocity of the incremental test and the ISRT distance correlated ($r=0.88$ $P<0.001$), and each correlated with v2 and v4 ($0.82<r<0.87$ $P<0.001$). In male soccer players, the maximum velocity during the incremental test was moderately correlated with v2 and v4 (v2: $r=0.58$ $P=0.037$; v4: $r=0.56$ $P=0.045$). In contrast to females, the ISRT distance did not correlate with the maximum velocity in the incremental test or with v2 and v4 ($0.02<r<0.55$ $P>0.05$) in male soccer players. Figure 2 clarifies the observed different correlations between v4 and ISRT distance in both genders. In both genders, v2 and v4 correlated with each other (females: $r=0.97$ $P<0.001$; males: $r=0.92$ $P<0.001$).

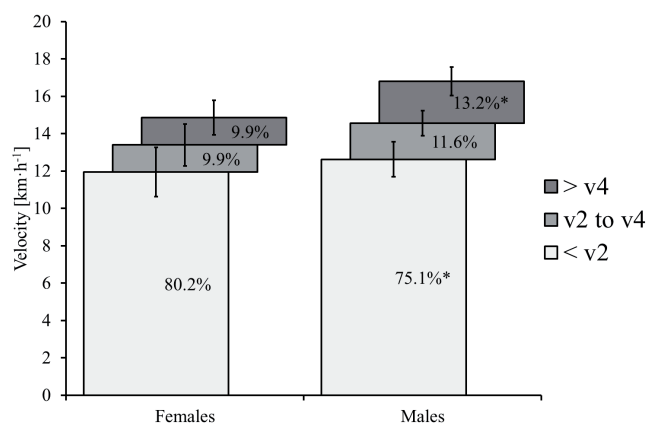


FIG. 1. THREE INTENSITY ZONES OF FEMALE AND MALE SOCCER PLAYERS BASED ON THE RUNNING VELOCITIES AT 2 AND 4 MMOL·L⁻¹ BLOOD LACTATE [V2 AND V4] AND THEIR PERCENTAGES IN RELATION TO THE MAXIMUM RUNNING VELOCITY IN THE INCREMENTAL TEST. Note: * significant differences ($P<0.05$) between female and male soccer players [see Table 1]

TABLE 2. CORRELATION COEFFICIENTS BETWEEN ENDURANCE PARAMETERS IN FEMALE AND MALE SOCCER PLAYERS

	ISRT distance	IT v2	IT v4	IT v _{max}
<i>Females</i>				
ISRT distance		0.82**	0.86**	0.88**
IT v2	0.41		0.97**	0.83**
IT v4	0.55	0.92**		0.87**
IT v _{max}	0.02	0.58*	0.56*	
<i>Males</i>				

Note: ** $P<0.01$; * $P<0.05$; ISRT – Interval shuttle run test; IT – Incremental test; v2 – Running velocity at 2 mmol·l⁻¹ blood lactate; v4 – Running velocity at 4 mmol·l⁻¹ blood lactate; v_{max} – Maximum running velocity.

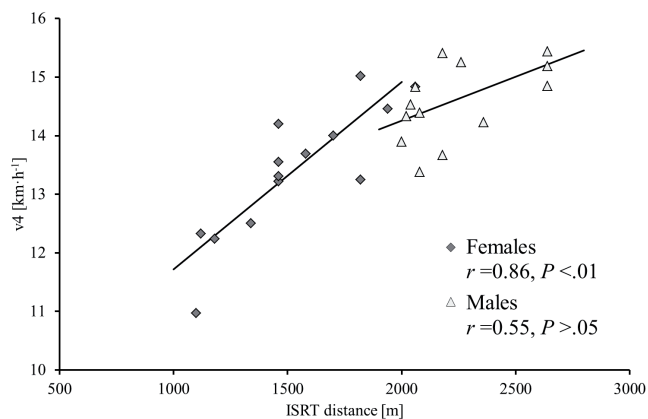


FIG. 2. LINEAR REGRESSION OF RUNNING VELOCITY AT 4 MMOL·L⁻¹ BLOOD LACTATE [V4] AND ISRT DISTANCE IN FEMALE AND MALE SOCCER PLAYERS

DISCUSSION

The aims of the present study were to assess gender differences regarding lactate threshold and intermittent shuttle run performance in female and male soccer players as well as to investigate the relationships between both endurance characteristics in both genders.

The main findings were that female, compared to male soccer players, have a lower v_4 (8.2%) and maximum running velocity (11.3%) during the incremental test, and cover less distance (31.6%) during the ISRT. Moreover, significant correlations were found between both lactate thresholds (v_2 and v_4) and ISRT distance in female but not in male soccer players.

In female players, the assessed v_2 (11.9 km·h⁻¹) is in agreement with values reported previously (10–13 km·h⁻¹) [16]. However, the measured v_4 (13.4 km·h⁻¹) is not in line with previous data (10 km·h⁻¹) from another study, reflecting different training statuses [13]. To date there exist no data regarding the distance covered during the ISRT in female soccer players. However, our results (1536 m) are comparable to those of elite female hockey players (1300 m) [19]. In male soccer players, the evaluated v_2 and v_4 (12.6 and 14.6 km·h⁻¹) are comparable to those from previous studies (v_2 : 13.1 km·h⁻¹; v_4 : 14.7 and 15.7 km·h⁻¹) [10,21]. However, the ISRT distance (2245 m) of male soccer players is similar as reported before (2210 m) [17].

With respect to the first aim, our results revealed gender differences in v_4 (8.2%) and maximum running velocity (11.3%). In a similar context, previous research assessed comparable gender differences in endurance running disciplines [26]. For example, the best 10 females in endurance running disciplines (1500 m to marathon) at the Olympic Games in Beijing 2008 were 10 to 20% slower than the males. However, our results indicate much larger gender differences in the ISRT distance (31.6%). Large gender differences were also found by a previous study investigating Yo-Yo test

performance (49%) [25]. Supported by previous studies, our results indicate that gender differences increase when the running performance is intermittent and nonlinear. Interestingly, the observed gender differences at the ISRT distance (31.6%) are comparable to those regarding the performed high intensity running distance during competitive matches (33%) [16]. Therefore, gender differences in high intensity running during matches may be explained to a greater extent by intermittent shuttle run performance than by lactate thresholds.

Figure 1 shows the gender differences of the three intensity zones for the running performance during the incremental test. The percentage of the zone $<v_2$ was greater in female players compared to the males. Therefore, relative to their maximum running velocity, female soccer players are able to achieve higher intensities without an increase in blood lactate above 2 mmol·l⁻¹. Also, gender differences exist in the intensity zone $>v_4$, reflecting the fact that male soccer players require more anaerobic glycolytic energy to achieve their maximum running velocity. These observations show that, at least in part, the incremental exercise running performances of female and male players consist of different distributions of aerobic and anaerobic metabolic pathways.

Generally, absolute differences in endurance performance between females and males are explainable by higher body fat (as well as less muscle mass) and maximum oxygen uptake as well as lower levels of haemoglobin in females [28]. Also, a lower training status in female soccer players as a result of a worse infrastructure (e.g., staff, pitches, equipment), as well as less experience and lower quality and quantity of training, may additionally explain our observed gender differences. The gender differences contributing to the three intensity zones may be explainable by different energy metabolisms, higher fat as well as less carbohydrate and amino acid oxidation in females [32].

Considering our second aim, only in female soccer players were v_2 , v_4 and v_{max} correlated with the ISRT distance ($r=0.82$ and $r=0.86$). A recent study revealed a correlation between v_2 and Yo-Yo test performance ($r=0.73$ $P=0.003$) in female soccer players [16]. In contrast, no correlation was found between v_2 , v_4 and v_{max} and ISRT performance in male soccer players, confirming previous research [12]. These data may hypothetically show that the predominantly aerobic metabolism, as assessed here via the lactate threshold, is more important for intermittent running performance in female than in male soccer players. Male players seem to accomplish their maximum intermittent running performance with aerobic and anaerobic metabolism in a more individual way. Thus, lactate measurements in incremental exercise tests are not valid to predict intermittent shuttle run performance in male soccer players [1,12].

At the present time there is no test that allows an accurate assessment of soccer-specific anaerobic power and capacity testing, due to the fact that aerobic and anaerobic metabolism are fundamentally connected to each other [6]. Especially in female soccer players, further studies should investigate how anaerobic metabolism can be developed, and how this development affects their intermittent

shuttle run performance. Additionally, it may be evaluated how gender differences obtained from performance assessments are related to running activities during matches.

CONCLUSIONS

The present study demonstrated that female and male soccer players have different endurance characteristics. The results revealed gender differences of 11.3% and 31.6% in incremental and interval shuttle run testing. During incremental testing, the running performances of female and male players reflect different distributions of aerobic and anaerobic metabolic pathways. Gender differences increase when the running performance is intermittent and

nonlinear (i.e., soccer specific). From a practical point of view, based on the present findings and our experiences in elite soccer, female soccer training should focus on strength and high intensity endurance training.

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Conflict of interest

The authors declared no conflict of interest.

REFERENCES

- Bangsbo J., Lindquist F. Comparison of various exercise tests with endurance performance during soccer in professional players. *Int. J. Sports Med.* 1992;13(2):125-132.
- Bangsbo J., Iaia F.M., Krstrup 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.
- Beneke R., Leithauser R.M., Ochentel O. Blood lactate diagnostics in exercise testing and training. *Int. J. Sports Physiol. Perform.* 2011;6(1):8-24.
- Bradley P.S., Sheldon W., Wooster B., Olsen P., Boanas P., Krstrup P. High-intensity running in English FA Premier League soccer matches. *J. Sports Sci.* 2009;27(2):159-168.
- Bradley P.S., Bendiksen M., Dellal A., Mohr M., Wilkie A., Datson N., Orntoft C., Zebis M., Gomez-Diaz A., Bangsbo J., Krstrup P. The application of the Yo-Yo intermittent endurance level 2 test to elite female soccer populations. *Scand. J. Med. Sci. Sports.* 2014;24(1):43-54.
- Brooks G.A. Lactate: link between glycolytic and oxidative metabolism. *Sports Med.* 2007;37(4-5):341-343.
- Cohen J. *Statistical power analysis for the behavioral sciences.* 2nd ed. Hillsdale, N.J.: Lawrence Erlbaum Associates; 1988. p. 284-291.
- Di Salvo V., Gregson W., Atkinson G., Tordoff P., Drust B. Analysis of high intensity activity in Premier League soccer. *Int. J. Sports Med.* 2009;30(3):205-212.
- Faude O., Kindermann W., Meyer T. Lactate threshold concepts: how valid are they? *Sports Med.* 2009;39(6):469-490.
- Guner R., Kunduracioglu B., Ulkar B., Ergen E. Running velocities and heart rates at fixed blood lactate concentrations in elite soccer players. *Adv. Ther.* 2005;22(6):613-620.
- Hoff J. Training and testing physical capacities for elite soccer players. *J. Sports Sci.* 2005;23(6):573-582.
- Hoppe M.W., Baumgart C., Sperlich B., Ibrahim H., Jansen C., Willis S.J., Freiwald J. Comparison between three different endurance tests in professional soccer players. *J. Strength Cond. Res.* 2013;27(1):31-37.
- Ingebrigtsen J., Dillern T., Shalfawi S.A. Aerobic capacities and anthropometric characteristics of elite female soccer players. *J. Strength Cond. Res.* 2011;25(12):3352-3357.
- Joyner M.J., Coyle E.F. Endurance exercise performance: the physiology of champions. *J. Physiol.* 2008;586(1):35-44.
- Krstrup P., Mohr M., Amstrup T., Rysgaard T., Johansen J., Steensberg A., Pedersen P.K., Bangsbo J. The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Med. Sci. Sports Exerc.* 2003;35(4):697-705.
- Krstrup P., Mohr M., Ellingsgaard H., Bangsbo J. Physical demands during an elite female soccer game: importance of training status. *Med. Sci. Sports Exerc.* 2005;37(7):1242-1248.
- Lemmink K.A., Verheijen R., Visscher C. The discriminative power of the Interval Shuttle Run Test and the Maximal Multistage Shuttle Run Test for playing level of soccer. *J. Sports Med Phys Fitness.* 2004;44(3):233-239.
- Lemmink K.A., Visscher C., Lambert M.I., Lamberts R.P. The interval shuttle run test for intermittent sport players: evaluation of reliability. *J. Strength Cond Res.* 2004;18(4):821-827.
- Lemmink K.A., Visscher S.H. Role of energy systems in two intermittent field tests in women field hockey players. *J. Strength Cond. Res.* 2006;20(3):682-688.
- Lemmink K.A.P.M., Visscher C. The relationship between the Interval Shuttle Run Test and maximal oxygen uptake in soccer players. *J. Hum Mov. Stud.* 2003;45(3):219-232.
- McMillan K., Helgerud J., Grant S.J., Newell J., Wilson J., Macdonald R., Hoff J. Lactate threshold responses to a season of professional British youth soccer. *Br. J. Sports Med.* 2005;39(7):432-436.
- Midgley A.W., McNaughton L.R., Jones A.M. Training to enhance the physiological determinants of long-distance running performance: can valid recommendations be given to runners and coaches based on current scientific knowledge? *Sports Med.* 2007;37(10):857-880.
- Mohr M., Krstrup P., Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J. Sports Sci.* 2003;21(7):519-528.
- Mohr M., Krstrup P., Andersson H., Kirkendall D., Bangsbo J. Match activities of elite women soccer players at different performance levels. *J. Strength Cond. Res.* 2008;22(2):341-349.
- Mujika I., Santisteban J., Impellizzeri F.M., Castagna C. Fitness determinants of success in men's and women's football. *J. Sports Sci.* 2009;27(2):107-114.
- Nimmo M.A. The female athlete. In: Maughan R.J., editor. *Olympic textbook of science in sport.* West-Sussex: Wiley-Blackwell; 2009. p.382-397.
- Pallant J. *SPSS survival manual : a step by step guide to data analysis using SPSS.* 4th ed. Maidenhead: McGraw-Hill; 2010. p. 243-247.
- Sandbakk O., Ettema G., Holmberg H.C. Gender differences in endurance performance by elite cross-country skiers are influenced by the contribution from poling. *Scand J. Med. Sci. Sports.* 2012.
- Seiler K.S., Kjerland G.O. Quantifying training intensity distribution in elite endurance athletes: is there evidence for an „optimal” distribution? *Scand J Med Sci Sports.* 2006;16(1):49-56.
- Stratton E., O'Brien B.J., Harvey J., Blitvich J., McNicol A.J., Janissen D, Paton C., Knez W. Treadmill velocity best predicts 5000-m run performance. *Int. J. Sports Med.* 2009;30(1):40-45.
- Svensson M., Drust B. Testing soccer players. *J. Sports Sci.* 2005;23(6):601-618.

32. Tarnopolsky M.A. Sex differences in exercise metabolism and the role of 17-beta estradiol. *Med Sci Sports Exerc.* 2008;40(4):648-654.
33. Wassermann K., Hansen J.E., Sue D.Y., Stringer W.W., Whipp B.J. Principles of exercise testing and interpretation. 4th ed. Philadelphia: Lippincott Williams&Wilkins; 2005. p. 168f.
34. Weltman A., Snead D., Stein P., Seip R., Schurrer R., Rutt R., Weltman J. Reliability and validity of a continuous incremental treadmill protocol for the determination of lactate threshold, fixed blood lactate concentrations, and VO₂max. *Int. J. Sports Med.* 1990;11(1):26-32.
35. Ziogas G.G., Patras K.N., Stergiou N., Georgoulis A.D. Velocity at lactate threshold and running economy must also be considered along with maximal oxygen uptake when testing elite soccer players during preseason. *J. Strength Cond. Res.* 2011;25(2):414-419.