Aerobic fitness and performance in elite female futsal players

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ABSTRACT: Despite its growing popularity, few studies have investigated specific physiological demands for elite female futsal. The aim of this study was to determine aerobic fitness in elite female futsal players using laboratory and field testing. Fourteen female futsal players from the Venezuelan National team (age =21.2±4.0 years; body mass =58.6±5.6 kg; height =161±5.0 cm) performed a progressive maximal treadmill test under laboratory conditions. Players also performed a progressive intermittent futsal-specific field test for endurance, the Futsal Intermittent Endurance Test (FIET), until volitional fatigue. Outcome variables were exercise heart rate (HR), VO_2, post-exercise blood lactate concentrations ([La]b) and running speeds ($km \cdot h^{-1}$). During the treadmill test, VO_2max, maximal aerobic speed (MAS), HR and peak [La]b were 45.3±5.6 $ml \cdot kg^{-1} \cdot min^{-1}$, 12.5±1.77 $km \cdot h^{-1}$, 197±8 $beats \cdot min^{-1}$ and 11.3±1.4 $mmol \cdot l^{-1}$, respectively. The FIET total distance, peak running velocity, peak HR and [La]b were 1125.0±121.0 m, 15.2±0.5 $km \cdot h^{-1}$, 199±8 $beats \cdot min^{-1}$ and 12.5±2.2 $mmol \cdot l^{-1}$, respectively. The FIET distance and peak speed were strongly associated (r= 0.85-87, $p<0.0001$) with VO_2max and MAS, respectively. Peak HR and [La]b were not significantly different between tests. Elite female futsal players possess moderate aerobic fitness. Furthermore, the FIET can be considered as a valid field test to determine aerobic fitness in elite level female futsal players.

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INTRODUCTION

Futsal is the worldwide popular indoor version of soccer, and it is recognized by the Federation Internationale de Football Association (FIFA). This sport is played at the professional and amateur level by millions of player of either gender [1]. Futsal is played between two teams of five players, each of them consisting of one goalkeeper and four outfield players. Futsal courts are mainly built in indoor facilities and their dimensions are 25-42 m long and 15-25 m wide. A futsal match consists of two halves of 20 minutes. However, the clock is stopped for some events (fouls, off-side, etc) and futsal match duration is 75 to 85% longer than 40 min [2]. Teams are allowed to request a 1 min time-out during each half, and there is a 10 min break between halves [2, 3]. However, the most relevant rule with regard to the physical demands of futsal is the possibility of unlimited substitutions during play. This means that players exercise at high intensity for 3-6 min before being changed [3], which in turn means that indoor soccer players require slightly different physical fitness than their outdoor soccer counterparts [4].

Analyses of movement demands in futsal have revealed that players run more than 4500 metres during a competitive match [5]. Futsal players perform an average of 9 exercise activities per minute of play, and there is a high intensity effort each 23 s of play [6]. The average intensity of futsal play is typically of a magnitude that yields 85-90% of maximal heart rate (HR_{max}) and 75% of VO_{2max} [3, 7]. Such relative intensity is similar to that reported in professional basketball players [3]. Energy is predominantly derived from the aerobic system [3] although during high-intensity efforts the primary energy contribution is from anaerobic metabolism [2, 3]. As a result of the nature of futsal rules, this game requires high aerobic fitness along with well-developed anaerobic pathways [8-11].

Despite the growing interest in futsal performance, the information related to training and the physical demands of matches has been focused only on elite male players [2, 3]. Given the evidence of gender difference in team sport performance [12, 13], information on aerobic fitness in elite female futsal players would be of great interest for coaches and sport scientists [14-16].

Recently, there has been proposed an intermittent futsal-specific shuttle running test (i.e. FIET) designed to replicate the movement demands of futsal [17]. The test protocol consists of 3 x 15 m shuttle-running bouts at increasing velocities, interspersed with 10 or 30 seconds recovery at set distances until exhaustion (i.e. total distance as outcome; [17]). The FIET was reported to be a valid test to assess specific high-intensity endurance in well-trained male futsal players under field conditions. However, information related to applicability of the FIET in elite female futsal players is currently not available (i.e. population validity).

Therefore, the first aim of the present study was to examine the aerobic fitness of top internationally ranked female futsal players; and secondly, to determine the validity of the FIET in an elite female futsal set-up. As the study hypothesis, it was assumed that female futsal players would possess excellent aerobic fitness, similar to their male counterparts.

MATERIALS AND METHODS

Participants. Fourteen outfield players from the female Venezuelan National Futsal Team volunteered to participate in this study. They had a mean ± standard deviation (SD) age of 21.2±4.0 years, height of 161.3± 5.0 cm, body mass of 58.6± 5.6 kg and body fat of 17.6± 3.4%. All participants were involved in regular futsal training (6-9 sessions per week with ~90 min duration per session) and competitions (a weekly match). Additionally, the participants had futsal experience of at least 5 years. The present research was conducted before the 2009 Latin-American International Championship. The Venezuelan National Futsal Team reached the third position in this Championship and they always reached the semi-finals in the Latin-American International Championships from 2007 to 2011. For these reasons, we classified this study sample as elite female futsal players. Players' written informed consent and clearance from the Ethics Committee of the Venezuelan National Institution for Sports was obtained before commencement of the study.

Ethics

The authors of this study declare that the experiments reported in this manuscript were performed in accordance with the ethical standards of the Helsinki Declaration and that the participants signed an informed consent form.

Experimental procedures

All players performed a treadmill test for VO_{2max} and the FIET in a randomized counterbalanced order at least 48 hours apart (i.e. the same hours of the day). In the 48 hours prior to testing, players did not perform any strenuous exercise, and they were encouraged to avoid alcohol, caffeine or tobacco before each test. Participants had a light meal at least 3 h before each testing. All players were familiarized with the protocols and procedures in purpose built sessions. During all testing, blood lactate concentration ($[La]_b$) was assessed

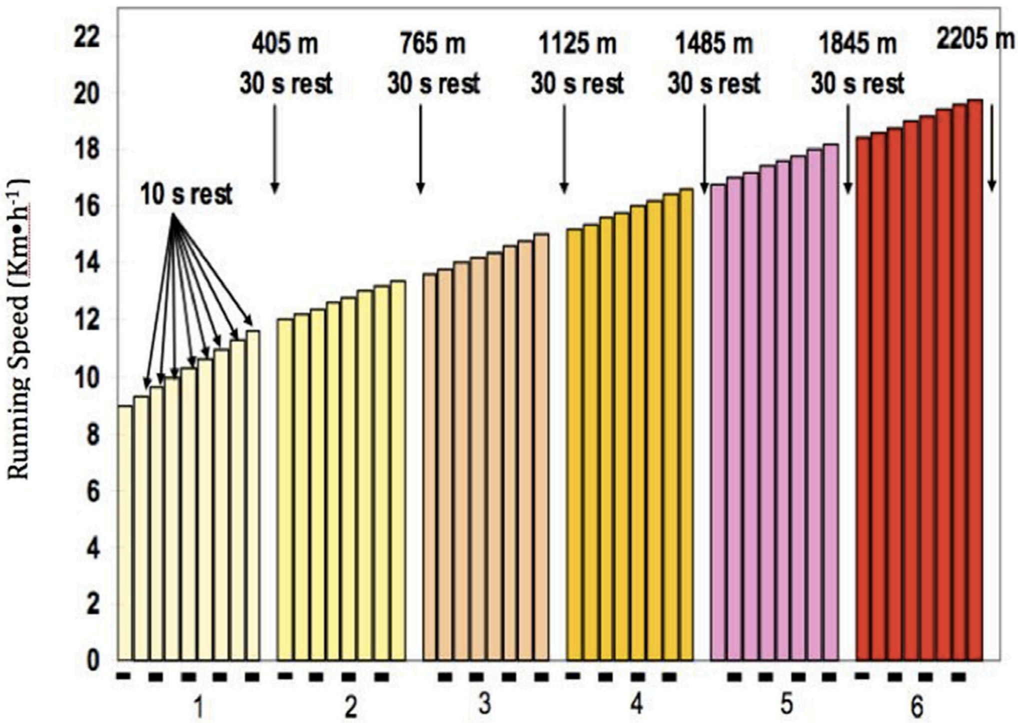

FIG. 1. Protocol of the Futsal Intermittent Endurance Test (FIET).

with a miniphotometer (LP20, Dr Lange, Germany) using earlobe capillary blood samples.

Laboratory testing

Aerobic fitness was assessed using a progressive treadmill running test until volitional exhaustion. Initial treadmill speed was set at 6 $km \cdot h^{-1}$, and it increased by 2 $km \cdot h^{-1}$ each 3 min. Respiratory gases were assessed with a breath-by-breath automatic gas analyzer (Ultima 20, Medgraphics, US). Heart rate was monitored using short range telemetry (Polar TS, Polar Electro Oy, Finland). Criteria for VO_{2max} were assumed as the attainment of at least two of the following conditions: a) absence of rises in VO_2 despite treadmill speed increments; b) a respiratory exchange ratio higher than 1.10; c) peak heart rate ± 10 $beats \cdot min^{-1}$ of the age-predicted maximum; d) a blood lactate concentration higher than 8 $mmol \cdot l^{-1}$ [18]. VO_{2max} was defined as the maximal 15-s value obtained during the test. The maximal aerobic speed (MAS) was calculated as previously described [19]. The ventilatory threshold was determined using the methodology previously described [20]. The HR_{max} was assumed as the highest 5-s value during the test.

Field testing

The FIET was performed on a wooden futsal court according to the procedures previously outlined [17]. Speeds were dictated (i.e. audio cues) by a CD player, and participants had to be on the front line in time with the current audio cue. The player's inability to be on time for two consecutive cues was used as the criterion for ending the FIET. Performance in the FIET was measured as: a) the distance covered until exhaustion, b) the total duration of the test, and c) the peak speed at exhaustion (FIET peak speed). Earlobe blood samples were withdrawn during macro pauses and at exhaustion for blood lactate concentration analysis.

Statistical analysis

Data are presented as mean± SD, 95% confidence intervals (95% CI) and ranges. Pearson's product-moment correlations were used to establish any relationships between the laboratory and the field measurements. Paired-samples t-tests were used to determine differences between laboratory and field measurements. The effect size (ES) was calculated to assess the meaningfulness of differences. Power calculations showed that 12 players were necessary to attain the set statistical significance. Statistical significance was considered at the 5% alpha level (i.e. $p<0.05$). All statistical analyses were completed using SPSS for Windows software, release 17.0 (SPSS Inc., Chicago, IL).

RESULTS

Table 1 depicts the results for the main variables obtained during the treadmill test. VO_{2max} was 45.3± 5.6 $ml \cdot kg^{-1} \cdot min^{-1}$ (37 to 50 $ml \cdot kg^{-1} \cdot min^{-1}$). Lactate threshold and ventilatory thresholds were obtained at 66± 2.4% and 80± 2.2% of VO_{2max}, respectively. HR_{max} was 197± 8 $beats \cdot min^{-1}$, with lactate and ventilatory thresholds corresponding to 81.0± 2.0 and 87.6± 2.5% of HR_{max}. MAS was obtained at 12.5± 1.8 $km \cdot h^{-1}$. Treadmill peak [La]b was 11.3± 1.4 $mmol \cdot l^{-1}$.

The FIET performance is presented in Table 2.

TABLE 1. Physiological variables measured in female futsal players during a maximal treadmill test.

Variable	Mean ± SD	95%CI	Range
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	45.3 ± 5.6	38.8 – 50.7	36.9 –52.2
VO_2 at VT ($ml \cdot kg^{-1} \cdot min^{-1}$)	36.2 ± 4.6	36.6 – 38.9	29.10 – 42
VO_2 at LT ($ml \cdot kg^{-1} \cdot min^{-1}$)	29.9 ± 4.3	25.9 – 33.8	22.60 – 35.90
$\%VO_2$ at VT	80 ± 2.2	79 – 81	76 – 83
$\%VO_2$ at LT	66 ± 2.4	65 – 67	62 – 69
HRmax ($beats \cdot min^{-1}$)	197 ± 8	192 – 202	187 – 212
HR at VT ($beats \cdot min^{-1}$)	172 ± 2	168 – 177	164 – 187
HR at LT ($beats \cdot min^{-1}$)	159 ± 8	155 – 164	149 – 173
%HRmax at VT	87.6 ± 2.5	79.6 – 82.5	76.0 – 84.2
%HRmax at LT	81.0 ± 2.0	86.5 – 88.8	83.7 – 90.5
[Lac]bmax ($mmol \cdot l^{-1}$)	11.3 ± 1.4	10.4 – 12.1	9.2 –13.2
LT ($mmol \cdot l^{-1}$)	4.06 ± 0.33	3.3 – 4.3	3.3 – 4.6
MAS ($km \cdot h^{-1}$)	12.5 ± 1.8	11.5 – 13.5	10.0 – 14.6
Vel. at VT ($km \cdot h^{-1}$)	9.8 ± 1.2	9.03 – 13.60	7.7 – 11.6
VEmax ($l \cdot min^{-1}$)	101.8 ± 11.03	95.5 – 108.2	83.3 – 119.0
VE at VT ($l \cdot min^{-1}$)	72.8 ± 8.2	68.5 – 77.5	58.4 – 82.1
%VEmax at VT	72.0 ± 2.6	70.5 – 73.5	68.3 – 76.6

Note: MAS= maximal aerobic speed; LT= lactate threshold; VT= ventilatory threshold; HR= heart rate; VE= ventilation; [Lac]b=blood lactate concentration; Vel. at VT = velocity at VT.

TABLE 2. Performance during the Futsal Intermittent Endurance Test (FIET) in elite female futsal players.

Variable	Mean ± SD	95%CI	Range
Total Distance (m)	1125± 121	1055 – 1195	900 –1305
Total Time (min)	10.3± 1.1	9.74 – 10.98	8.5–12
Peak Speed ($km \cdot h^{-1}$)	15.2± 0.5	14.69 – 15.31	14.2 – 15.8
HRpeak ($beats \cdot min^{-1}$)	199±8	195 – 203	190– 217
[La]b peak ($mmol \cdot l^{-1}$)	12.5± 2.2	11.0 – 13.3	8.4– 15.1

Note: HR= Heart Rate; [Lac]b=Blood Lactate Concentration.

The FIET distance was strongly correlated with VO_{2max} (r=0.87; p<0.0001; 95%CI 0.62–0.96), running speed at the ventilatory threshold (r=0.83, p<0.001, 95%CI 0.51–0.94), VO_2 at the ventilatory threshold (r=0.83, p<0.001, 95%CI 0.52–0.94 respectively) and VO_2 at the lactate threshold (r=0.83, p<0.001, 95%CI 0.53–0.94). The MAS and FIET peak speed were very strongly associated (r=0.85, p=0.0001, 95%CI 0.59 –0.95). The FIET peak HR during the test was not found to be significantly different from the HR_{max} (diff.=2.07; p=0.12; 95%CI -0.61 to 4.76; ES=0.45). No significant differences were observed between the FIET and treadmill peak [La]b (diff.=-0.88; p=0.11, 95%CI -2.00–0.25; ES=0.47).

DISCUSSION

This is the first study that has examined aerobic fitness and specific endurance in elite level female futsal players. The results obtained in this investigation, during a maximal running test to volitional exhaustion (i.e., VO_{2max} = 45.3 ± 5.6 ml·kg^{-1}·min^{-1}), were lower than the ones reported in elite and professional female soccer players (from 49 to 58 ml·kg^{-1}·min^{-1}; [14, 21-23]). However, the values of elite female futsal players were similar to the values described for female collegiate soccer players (from 44 to 47 ml·kg^{-1}·min^{-1}; [24-26]). Additionally, the VO_{2max} values of female futsal players were remarkably lower than those reported in male futsal players competing at the professional [3, 9], semi-professional [9] and recreational levels [7]. Although similar gender differences have been recently found for soccer players during incremental and interval shuttle run testing [13] until volitional fatigue, these comparisons suggest that elite level female futsal players have moderate VO_{2max} values, at least in comparison to female soccer players of similar level. In addition, these data suggest that elite female futsal players can benefit from high-intensity endurance training to improve aerobic fitness, at least to obtain the values obtained in elite female soccer.

Unlike elite male futsal players [3, 27], female futsal players seem to possess lower levels of VO2max than competitive level matched soccer players [14]. The reasons for the disparity in aerobic fitness between male and female futsal players are difficult to explain with this research design (i.e. descriptive). Besides methodological reasons, sex, genetics and differences in training load may be considered as explanatory factors [28, 29]. Although these values might be representative of the elite level female players, the sample size used for the present investigation and the nature of the experimental design do not allow us to establish VO2max normative or evidence-based suggestions for female futsal [3, 9]. In this regard, more information may be gained by carrying out research that includes a direct comparison of both sexes and/or by using ecologically valid contexts (match, simulated match, and training situations; [3, 30, 31]).

In this study, female futsal players attained their MAS at 12.5± 1.7 km·h^{-1} and their ventilatory threshold at 9.8±1.4 km·h^{-1} during the treadmill test. These values are considerably lower than those reported in professional male futsal players (i.e. 18.3 km·h^{-1} for MAS and 12.9 km·h^{-1} for ventilatory threshold; [3]). Barbero-Alvarez et al. [9], in their cross-sectional study, reported MAS and speed at ventilatory threshold values in the range of 17.3-17.7 kmkm·h^{-1} and 12-12.2 km·h^{-1} for semi-professional and professional male futsal players, respectively. Despite the differences in the methodology used to calculate the speed at VO_{2max} (i.e. estimated vs direct calculation), the differences in "absolute" aerobic fitness between male and female futsal players suggest that females possess a lower work capacity in comparison to male futsal players matched for age and competitive level [3, 9]. However, these differences may be reduced when comparing male and female relative variables [27].

In this study, the female futsal players attained their ventilatory threshold at 80± 2.2% of the VO_{2max}. Interestingly, this value was closer to VO_{2max} than previously reported by Castagna et al. [3] (71%) and Barbero-Alvarez et al. [9] (70-71%) in male futsal players. However, the ventilatory threshold in female futsal players occurred at a %HRmax (87 vs 84%) similar to those reported for professional and semi-professional male futsal players [3, 9]. This may suggest that, despite their low VO_{2max} values, the investigated female population showed reasonably well-developed sub-maximal aerobic fitness [32]. The reasons for this result cannot be properly addressed with this research design. Given that the approximation of the intensity that produces the ventilatory threshold to VO_{2max} may be a consequence of peripheral adaptations due to training and competitions [33-35], the values found in female futsal players in submaximal aerobic fitness might indicate the occurrence of exercise mode related physiological adaptations.

Female futsal players' FIET performance (i.e. 1125± 121 m) was 23% lower than that previously reported in professional male futsal players (1464±136m; [9]). Sex differences in specific endurance testing have been previously reported by Mujika et al. [12] in highly competitive professional soccer players performing the Yo-Yo intermittent recovery test level 1. However, in the Mujika et al. [12] study, a remarkably greater difference in specific endurance was reported when comparing professional male and female counterparts (i.e. 49%). Additionally, gender differences increased to 53% when comparing both males and females of junior categories [12]. Despite differences in the nature of the sport (i.e. soccer vs futsal) and in the endurance tests employed (i.e. Yo-Yo IR1 vs FIET), this study confirms the existence of sex differences in specific endurance in team sport players [12, 36]. Interestingly, the differences in specific endurance have been reported to be the main cause for the significantly lower work-rate ratio found in female soccer players [14, 27]. It could be speculated that aerobic training interventions may be successful in improving female players' work capacity during actual match play, thus reducing the observed difference with their male counterparts [37].

The FIET was reported to heavily stress both the aerobic and anaerobic pathways in professional male futsal players [10]. However, no significant correlation was reported between the FIET performance and the inter-individual level of VO_{2max}. Furthermore, the FIET performance only showed a strong association with MAS, speed at ventilatory threshold and peak treadmill speed. This is in contrast to the results of this study that showed strong associations between individual relative VO_{2max}, VO_2 at selected anaerobic threshold measures and MAS with the distance achieved during the FIET. These different magnitudes of associations may be the result of a dissimilar training intervention, fitness level and or gender difference in physiological make-up. Further studies addressing the effect of generic or specific aerobic training on the FIET performance related to gender are warranted.

Similarly to what was reported for professional male futsal players, the FIET peak HR and [La]b were not significantly different from maximal values obtained during the treadmill testing (Table 2 and Table 3). These data indicate that the FIET may be considered as a specific endurance test that heavily challenges the aerobic and anaerobic pathways of elite level female futsal players.

CONCLUSIONS

In summary, elite female futsal players presented moderate levels of aerobic fitness, based on the comparison to female soccer players of similar level and age. The modest aerobic fitness values found in female futsal players might not be related to the characteristics of the game, because male futsal players have similar aerobic fitness to male soccer counterparts [3, 27]. Thus, futsal specific training in females and the intensity reached during official matches may not constitute an effective stimulus for VO_{2max} development in this population, perhaps related to the low development of this sport when compared to other disciplines. Recent studies have shown that high-intensity practices in the form of ball drills and interval running are effective in eliciting short-term (i.e. 4-12 weeks) aerobic fitness development in soccer [37]. Improvements were also reported in the speed at selected maximal and sub-maximal aerobic fitness variables [37]. This scientific information may suggest the need of high-intensity aerobic training in female futsal players, beyond the current practices/routines. Finally, the FIET can be considered as a valid field test to assess aerobic and anaerobic fitness in female futsal players.

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REFERENCES

1. FIFA. The FIFA Big Count 2006: 230 million active in football.: FIFA Communications Division., 2007:PDF Download (http://www.fifa.com/search/index.htmx?q=big+count) 2007 [cited accessed June 2008].
2. Barbero-Alvarez JC, Soto VM, Barbero-Alvarez V, Granda-Vera J. Match analysis and heart rate of futsal players during competition. J Sports Sci. 2008;26(1):63-73.
3. Castagna C, D'Ottavio S, Vera JG, Alvarez JC. Match demands of professional Futsal: A case study. J Sci Med Sport. 2009;12(4):490-4.
4. Gorostiaga EM, Llodio I, Ibanez J, Granados C, Navarro I, Ruesta M, et al. Differences in physical fitness among indoor and outdoor elite male soccer players. Eur J Appl Physiol. 2009;106(4):483-91.
5. Makaje N, Ruangthai R, Arkarapanthu A, Yoopat P. Physiological demands and activity profiles during futsal match play according to competitive level. J Sports Med Phys Fitness. 2012;52(4):366-74.
6. Barbero-Alvarez JC, Soto VM, Granda-Vera J. Effort profiling during indoor soccer competition. J Sports Sci. 2004;22(1):500-1.
7. Castagna C, Belardinelli R, Impellizzeri FM, Abt GA, Coutts AJ, D'Ottavio S. Cardiovascular responses during recreational 5-a-side indoor-soccer. J Sci Med Sport. 2007;10(2):89-95.
8. Stone NM, Kilding AE. Aerobic Conditioning for Team Sport Athletes. Sports Med. 2009;39 (8):615-42.
9. Barbero-Alvarez JC, D'Ottavio S, Vera JG, Castagna C. Aerobic fitness in futsal players of different competitive level. J Strength Cond Res. 2009;23(7):2163-6.
10. Castagna C, Barbero Alvarez JC. Physiological demands of an intermittent futsal-oriented high-intensity test. J Strength Cond Res. 2010;24(9):2322-9.
11. Dupont G, Millet GP, Guinhouya C, Berthoin S. Relationship between oxygen uptake kinetics and performance in repeated running sprints. Eur J Appl Physiol. 2005;95(1):27-34.
12. Mujika I, Santisteban J, Impellizzeri FM, Castagna C. Fitness determinants of success in men's and women's football. J Sports Sci. 2009;27(2):107-14.
13. Baumgart C, Hoppe MW, Freiwald J. Different endurance characteristics of female and male german soccer players. Biol Sport. 2014;31(3):227-32.
14. Krustrup 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):1242-8.
15. Ziv G, Lidor R. Physical Attributes, Physiological Characteristics, On-Court Performances and Nutritional Strategies of Female and Male Basketball Players. Sports Med. 2009;39(7):547-68.
16. Ziv G, Lidor R. Vertical jump in female and male basketball players. A review of observational and experimental studies. J Sci Med Sport. 2010;13(3):332-9.
17. Barbero-Alvaréz JC, Andrín G, Méndez-Villanueva A. Futsal-specific endurance assessment of competitive players. J Sports Sci. 2005;23(11-12):1279-81.
18. Midgley AW, McNaughton LR, Polman R, Marchant D. Criteria for determination of maximal oxygen uptake: a brief critique and recommendations for future research. Sports Med. 2007;37(12):1019-28.
19. Margaria R, Aghemo P, Piñera Limas F. A simple relation between performance and maximal aerobic power. J Appl Physiol. 1975;38(2):351-3.
20. Beaver WL, Wasserman K, Whipp BJ. A new method for detecting anaerobic threshold by gas exchange. J Appl Physiol. 1986;60(6):2020-7.
21. Datson N, Hulton A, Andersson H, Lewis T, Weston M, Drust B, et al. Applied physiology of female soccer: an update. Sports Med. 2014;44(9):1225-40.
22. Martinez-Lagunas V, Hartmann U. Validity of the Yo-Yo Intermittent Recovery Test Level 1 for direct measurement or indirect estimation of

maximal oxygen uptake in female soccer players. Int J Sports Physiol Perform. 2014;9(5):825-31.
23. Haugen TA, Tonnessen E, Hem E, Leirstein S, Seiler S. VO2max characteristics of elite female soccer players, 1989-2007. Int J Sports Physiol Perform. 2014;9(3):515-21.
24. Esco MR, Snarr RL, Flatt A, Leatherwood M, Whittaker A. Tracking changes in maximal oxygen consumption with the heart rate index in female collegiate soccer players. J Hum Kinet. 2014;42:103-11.
25. Esco MR, Snarr RL, Williford HN. Monitoring changes in VO2max via the Polar FT40 in female collegiate soccer players. J Sports Sci. 2014;32(11):1084-90.
26. Miller TA, Thierry-Aguilera R, Congleton JJ, Amendola AA, Clark MJ, Crouse SF, et al. Seasonal changes in VO2max among Division 1A collegiate women soccer players. J Strength Cond Res. 2007;21(1):48-51.
27. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of Soccer: An Update. Sports Med. 2005;35(6):501-36.
28. Manzi V, Iellamo F, Impellizzeri F, D'Ottavio S, Castagna C. Relation between individualized training impulses and performance in distance runners. Med Sci Sports Exerc. 2009;41(11):2090-6.
29. Manzi V, D'Ottavio S, Impellizzeri FM, Chaouachi A, Chamari K, Castagna C. Profile of weekly training load in elite male professional basketball players. J Strength Cond Res. 2010;24(5):1399-406.
30. Mujika I, Santisteban J, Castagna C. In-season effect of short-term sprint and power training programs on elite junior soccer players. J Strength Cond Res. 2009;23(9):2581-7.
31. Impellizzeri FM, Rampinini E, Marcora SM. Physiological assessment of aerobic training in soccer. J Sports Sci. 2005;23(6):583–92.
32. Pate RR, Kriska A. Physiological basis of the sex difference in cardiorespiratory endurance. Sports Med. 1984;1(2):87-98.
33. McMillan K, Helgerud J, Macdonald R, Hoff J. Physiological adaptations to soccer specific endurance training in professional youth soccer players. Br J Sports Med. 2005;39(5):273-7.
34. McMillan K, Helgerud J, Grant SJ, Newell J, Wilson J, Macdonald R, et al. Lactate threshold responses to a season of professional British youth soccer. Br J Sports Med. 2005;39(7):432-6.
35. Helgerud J, Engen LC, Wisløff U, Hoff J. Aerobic endurance training improves soccer performance. Med Sci Sports Exerc. 2001;33(11):1925-31.
36. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test : a useful tool for evaluation of physical performance in intermittent sports. Sports Med. 2008;38(1):37-51.
37. Helgerud J, Engen LC, Wisløff U, Hoff J. Aerobic endurance training improves soccer performance. Med Sci Sports Exerc. 2001;33(11):1925-31.