Gender endurance characteristics in soccer

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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-
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 incremental 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 (v2 and v4) were calculated by linear interpolation. The reliability of v2 and v4 has been previously reported [34]. The maximum running velocity (v_{max}) was also assessed. 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 (where blood lactate concentration is elevated but production and clearance are in equilibrium) (v2 to v4), and a lactate accumulation zone, where blood lactate production exceeds clearance (>v4) [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 v2, v4, 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.
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 $v_4$ ($P=0.003$) and maximum velocity ($P<0.001$), being higher in male compared to female players. There were no gender differences in $v_2$, maximum heart rate, 60 s heart rate recovery and maximum blood lactate concentration (all $P>0.05$). Additionally, the intensity zones $<v_2$ ($P=0.016$) and $>v_4$ ($P=0.032$) 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: $P<0.001$ $\eta^2=0.80$; males: $P<0.019$ $\eta^2=0.38$) 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 $v_2$ and $v_4$ ($0.82<r<0.87$ $P<0.001$). In male soccer players, the maximum velocity during the incremental test was moderately correlated with $v_2$ and $v_4$ ($v_2$: $r=0.58$ $P=0.037$; $v_4$: $r=0.56$ $P=0.045$). In contrast to females, the ISRT distance did not correlate with the maximum velocity in the incremental test or with $v_2$ and $v_4$ ($0.02<r<0.55$ $P>0.05$) in male soccer players. Figure 2 clarifies the observed different correlations between $v_4$ and ISRT distance in both genders. In both genders, $v_2$ and $v_4$ correlated with each other (females: $r=0.97$ $P<0.001$; males: $r=0.92$ $P<0.001$).

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

<table>
<thead>
<tr>
<th>Test</th>
<th>Parameter</th>
<th>Females [n=14]</th>
<th>Males [n=13]</th>
<th>$P$</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropometric characteristics</td>
<td>Age [years]</td>
<td>21.4 ± 4.6</td>
<td>22.8 ± 2.9</td>
<td>0.325</td>
<td>0.039</td>
</tr>
<tr>
<td></td>
<td>Body height [cm]</td>
<td>167 ± 5</td>
<td>181 ± 6</td>
<td>&lt;0.001</td>
<td>0.663</td>
</tr>
<tr>
<td></td>
<td>Body mass [kg]</td>
<td>59.5 ± 5.4</td>
<td>76.8 ± 6.9</td>
<td>&lt;0.001</td>
<td>0.683</td>
</tr>
<tr>
<td></td>
<td>Body mass index [kg·m⁻²]</td>
<td>21.4 ± 1.4</td>
<td>23.4 ± 1.5</td>
<td>0.001</td>
<td>0.347</td>
</tr>
<tr>
<td>Incremental test</td>
<td>Maximum heart rate [beats.min⁻¹]</td>
<td>184 ± 7</td>
<td>188 ± 7</td>
<td>0.130</td>
<td>0.089</td>
</tr>
<tr>
<td></td>
<td>60 s heart rate recovery [beats.min⁻¹]</td>
<td>33 ± 13</td>
<td>37 ± 10</td>
<td>0.494</td>
<td>0.019</td>
</tr>
<tr>
<td></td>
<td>Maximum blood lactate concentration [mmol·l⁻¹]</td>
<td>8.3 ± 1.9</td>
<td>9.7 ± 2.6</td>
<td>0.109</td>
<td>0.099</td>
</tr>
<tr>
<td></td>
<td>Running velocity at 2 mmol·l⁻¹ blood lactate ($v_2$) [km·h⁻¹]</td>
<td>11.9 ± 1.32</td>
<td>12.6 ± 0.94</td>
<td>0.138</td>
<td>0.086</td>
</tr>
<tr>
<td></td>
<td>Running velocity at 4 mmol·l⁻¹ blood lactate ($v_4$) [km·h⁻¹]</td>
<td>13.4 ± 1.11</td>
<td>14.6 ± 0.67</td>
<td>0.003</td>
<td>0.300</td>
</tr>
<tr>
<td></td>
<td>Maximum running velocity [km·h⁻¹]</td>
<td>14.9 ± 0.92</td>
<td>16.8 ± 0.76</td>
<td>&lt;0.001</td>
<td>0.586</td>
</tr>
<tr>
<td></td>
<td>Intensity zone $&lt;v_2$ [%]</td>
<td>80.2 ± 5.6</td>
<td>75.1 ± 4.6</td>
<td>0.016</td>
<td>0.209</td>
</tr>
<tr>
<td></td>
<td>Intensity zone $v_2$ to $v_4$ [%]</td>
<td>9.9 ± 2.7</td>
<td>11.6 ± 2.8</td>
<td>0.106</td>
<td>0.101</td>
</tr>
<tr>
<td></td>
<td>Intensity zone $&gt;v_4$ [%]</td>
<td>9.9 ± 3.9</td>
<td>13.2 ± 3.7</td>
<td>0.032</td>
<td>0.170</td>
</tr>
<tr>
<td>Interval shuttle run test</td>
<td>Running distance [m]</td>
<td>1536 ± 301</td>
<td>2245 ± 247</td>
<td>&lt;0.001</td>
<td>0.639</td>
</tr>
<tr>
<td></td>
<td>Maximum heart rate [beats.min⁻¹]</td>
<td>190 ± 6</td>
<td>192 ± 6</td>
<td>0.470</td>
<td>0.021</td>
</tr>
<tr>
<td></td>
<td>60 s heart rate recovery [beats.min⁻¹]</td>
<td>30 ± 8.4</td>
<td>33 ± 7.5</td>
<td>0.360</td>
<td>0.034</td>
</tr>
</tbody>
</table>

**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 ($v_2$ AND $v_4$) 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**

<table>
<thead>
<tr>
<th>ISRT distance</th>
<th>IT $v_2$</th>
<th>IT $v_4$</th>
<th>IT $v_{\text{max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISRT distance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT $v_2$</td>
<td>0.41</td>
<td>0.82**</td>
<td>0.86**</td>
</tr>
<tr>
<td>IT $v_4$</td>
<td>0.55</td>
<td>0.92**</td>
<td>0.97**</td>
</tr>
<tr>
<td>IT $v_{\text{max}}$</td>
<td>0.02</td>
<td>0.58*</td>
<td>0.56*</td>
</tr>
</tbody>
</table>

Note: ** $P<0.01$; * $P<0.05$; ISRT – Interval shuttle run test; IT – Incremental test; $v_2$ – Running velocity at 2 mmol·l⁻¹ blood lactate; $v_4$ – Running velocity at 4 mmol·l⁻¹ blood lactate; $v_{\text{max}}$ – Maximum running velocity.
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 v4 (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 (v2 and v4) and ISRT distance in female but not in male soccer players.

In female players, the assessed v2 (11.9 km·h⁻¹) is in agreement with values reported previously (10-13 km·h⁻¹) [16]. However, the measured v4 (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 [19]. In male soccer players, the evaluated v2 and v4 (12.6 and 14.6 km·h⁻¹) are comparable to those from previous studies (v2: 13.1 km·h⁻¹; v4: 14.7 and 15.7 km·h⁻¹) [10,21]. However, the ISRT distance (2245 m) of male soccer players is higher than in male soccer players. Male players seem to accomplish their maximum intermittent running performance with aerobic and anaerobic metabolism, as assessed here via the lactate threshold (v2) and 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 v2, v4, and vmax correlated with the ISRT distance (r=0.82 and r=0.86). A recent study revealed a correlation between v2 and Yo-Yo test performance (r=0.73 P=0.003) in female soccer players [16]. In contrast, no correlation was found between v2, v4, and vmax 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
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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