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Contrasts in intermittent endurance performance and heart rate response between female and male soccer players of different playing levels

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ABSTRACT: This study compared intermittent endurance performance and heart rate (HR) response, as well as their relationship, by sex and competitive level in soccer. A total of 68 outfield (18 elite and 16 sub-elite female, 17 elite and 17 sub-elite male) soccer players performed the Interval Shuttle Run Test (ISRT) with monitored HR. Sex and level effects were evaluated by two-way analysis of variance (ANOVA) and the relationships between parameters using Pearson's correlation coefficient. Female players presented lower performance (effect sizes [ES]: 2.12-4.71, $p < 0.01$) and higher submaximal HR during the ISRT (ES: 1.66-3.40, $p < 0.01$). Elite players showed higher performance and reduced submaximal HR compared with their sub-elite counterparts, with a *large* level effect only evident between the female groups (ES: 1.22-1.56, $p < 0.01$). The maximum and the HR recovery 1 min after the ISRT (HRR) did not differ among all groups (ES: 0.01-0.51, $p \geq 0.18$). The HRR was slightly related to the test performance for all groups ($r = 0.20$, $p = 0.12$). *Large* to *very large* negative correlations were verified between HR at 6 and 9 min during the ISRT and the test performance for each group ($r = -0.54$ to -0.84, $p \leq 0.04$). However, 16 (3 elite and 13 sub-elite) female players did not reach the 9th minute of the test. The gap between competitive levels among female soccer players is greater than that observed for male players in intermittent endurance performance and submaximal HR response. The HRR had only a minor impact on performance and was influenced neither by sex nor by level.

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INTRODUCTION

Intermittent endurance is an essential physical capacity for soccer players to fulfil the match demands of constant bouts of high-intensity running (HIR) interspersed with recovery periods [1–3]. Therefore, training, testing, and monitoring the intermittent endurance capacity are relevant practices in soccer [4]. Intermittent field tests are commonly applied to evaluate this in a soccer-specific, as well as in a cost- and time-efficient way [4]. The performance (e.g. distance covered) in such tests represents a more sensitive and valid parameter for soccer endurance capacity compared with others, such as time to exhaustion and maximum oxygen uptake (VO_2max) in the treadmill test [5]. In addition, the intermittent endurance performance during the field tests is related to the amount of HIR during the matches in female [6] and male soccer players [5]. Considering the above, the use of intermittent field tests is an ecologically valid procedure to assess the intermittent endurance capacity in soccer players.

The discriminative power of intermittent tests has been consistently attested within soccer players considering competitive levels [3, 4, 7–10], sexes [11, 12] and age groups [9, 10, 13], as well as their sensitivity to training adaptations [5, 9, 10, 14, 15]. Overall, higher performances have been reported for female [4, 9] and male [3, 7, 8, 10] players of higher competitive levels compared with those of lower levels, as well as for male players in comparison with their female counterparts [11, 12]. Along with the test performance, heart rate (HR) measurement has been widely used as a parameter by intermittent testing in soccer, providing further information about the training status of the players [5, 8, 10, 14, 15]. To the best of our knowledge, an investigation that directly examines the intermittent endurance performance and the HR response of female and male senior soccer players of different competitive levels by the same research design is still lacking. Such an investigation may provide a better understanding of the peculiarities, as well as further evidence to establish more specific training and testing interventions for the different groups in soccer.

Specifically, HR measurement is a useful tool for monitoring cardiovascular responses to effort, representing an internal indicator to evaluate its intensity as additional information to the external test load (e.g. distance, velocity, time to exhaustion, etc.) [16]. Thereby, the submaximal HR during intermittent field tests has been shown as sensitive to detect positive adaptations by decreasing after intervention in soccer players [5, 10, 15]. This could also be observed in regular submaximal intermittent testing during the season, with the advantage that the players do not have to perform until exhaustion throughout an already dense competitive schedule [15]. Moreover, lower submaximal HR values at minutes 2 and 4 during intermittent tests have been verified in male players of a higher competitive level than in those of a lower one [8]. Furthermore, the submaximal HR values at the 6th and 9th minutes of these tests have shown negative correlations with the test performance [5, 10], as well as with the peak values of HIR performed during matches [10]. Thus, monitoring submaximal HR response during intermittent field tests is a relevant complement to the analysis of specific endurance capacity in soccer.

HR recovery (HRR) after physical exertion is another common parameter considered in monitoring cardiovascular response [16, 17]. The HRR reflects the hemodynamic sympathetic and parasympathetic adjustments of the organisms [16]. A faster HRR after effort has been associated with improved performance in highly trained endurance athletes [18]. In addition, the cardiac autonomic modulation has been demonstrated as sex-dependent [19], since women have shown greater activity of the autonomic vagal component compared with men [20]. Nevertheless, some studies have reported improved cardiovascular recovery after effort for both untrained [21] and well-trained men [22]. Although there is some evidence in the literature [23], further research is still needed to attest the practical application of HRR monitoring in team sports [16]. Dellal et al. [24] verified, for example, a faster HRR immediately after an intermittent compared with a continuous field test in elite male soccer players. Sex and level differences in HRR after intermittent effort in soccer players have received little attention so far. Further investigation on possible sex and level influences on HRR in soccer is desirable to provide more evidence about its potential use [23].

Therefore, the present study proposed (1) to compare intermittent endurance performance and HR response during and after a field test by sex and competitive playing level within soccer players, and (2) to examine the relationship between the test performance and the submaximal HR values during, as well as the HRR after the test. Since the distance covered at higher speed thresholds during matches differs between sexes [1] and levels [2, 3], it is expected that the test performance will distinguish players by sex and level as well. Based on previous results [8, 11], we also hypothesize that there will be a sex and level effect on the submaximal HR responses. Differences in the HRR after intermittent effort considering sex and competitive playing level, and its modulation, remain to be elucidated, and this investigation may contribute to the topic.

MATERIALS AND METHODS

Design

In a noninterventional cross-sectional design, the intermittent endurance performance of elite and sub-elite female and male soccer players was assessed in order to investigate differences according to sex and competitive level. Thereby, the HR response of the players was monitored during and after the intermittent endurance test. The measurements occurred in the first half of the competitive season in the respective training facilities of the groups.

Participants

A total of 68 outfield soccer players participated in this study. Thirty-five were elite players from the highest German league (*Bundesliga*), 18 women and 17 men, while 33 were sub-elite players from the German fourth league, 16 women and 17 men. The competitive and

TABLE 1. Competitive and anthropometric characteristics of elite and sub-elite female and male soccer players (mean ± SD).

Characteristics	**Elite female**	**Sub-elite female**	**Elite male**	**Sub-elite male**
n	**18**	**16**	**17**	**17**
Playing level (league)	1st	4th	1st	4th
Training sessions/week	4	3	5–7	5–7
Match/week	1–2	1–2	1–2	1–2
Season period of the ISRT (round)	9th	12th	8th	10th
Age (years)	21 ± 4	25 ± 5	24 ± 4	24 ± 4
Body height (cm)	167 ± 4 *	167 ± 7 *	179 ± 5	181 ± 5
Body mass (kg)	62.1 ± 7.6 *	65.5 ± 13.1 *	76.3 ± 6.8	78.4 ± 7.2
Body mass index (kg/m^2)	22.4 ± 2.5	23.6 ± 4.2	23.9 ± 1.4	23.8 ± 1.7

*Significant different from elite and sub-elite male players; Body height: $p < 0.01$; Body mass: $p \leq 0.01$.
ISRT: Interval Shuttle Run Test.

anthropometric characteristics of the players are presented in Table 1. The study was approved by the Ethics Committee of the local university (MS/JE29.11.11) in accordance with the Declaration of Helsinki. All players were informed about the experimental procedures and risks before giving their consent. Parental consent was given for players under the age of 18.

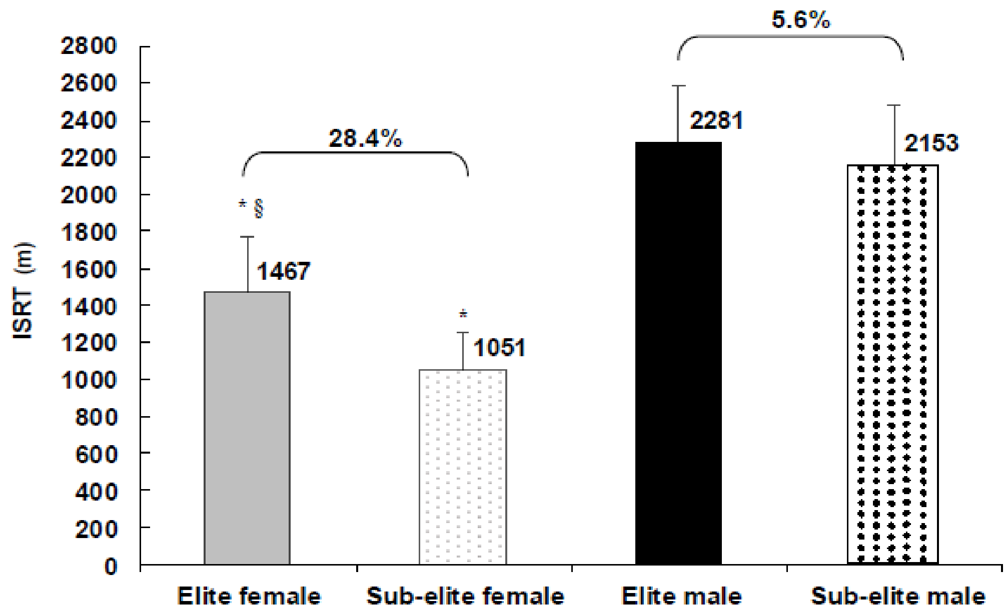

FIG. 1. Performance of elite and sub-elite female and male soccer players in the Interval Shuttle Run Test (ISRT).
Simple main sex and level effects: $p < 0.01$; Interaction effect: $p < 0.05$.
*Significant differences between sexes ($p < 0.01$). §Significant difference between levels ($p < 0.01$).

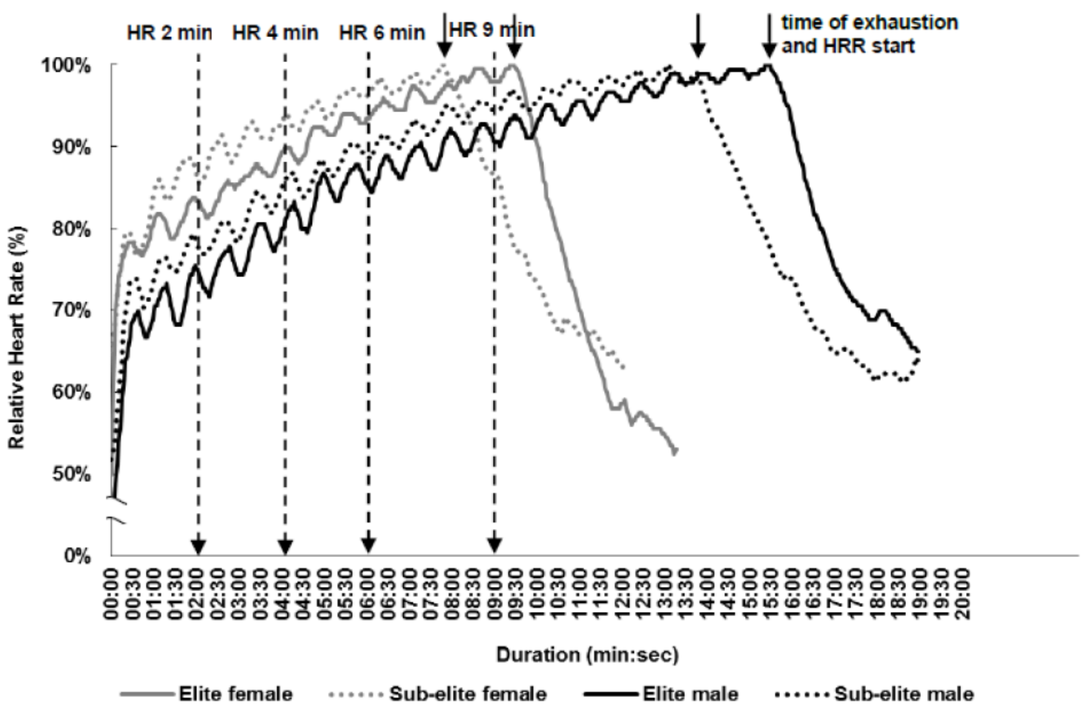

FIG. 2. Heart rate response of elite and sub-elite female and male soccer players during the Interval Shuttle Run Test.
HR: heart rate; HRR: heart rate recovery one minute after.
Note: Figure 2 shows examples of the response of one player from each group, whose values well represent the mean of their respective groups. The dashed vertical lines indicate the minutes selected for analyses. The black arrows indicate the respective time of exhaustion and start of the recovery phase.

Procedures

The intermittent endurance test was carried out at least 48 hours after a match, in one session for each group before their usual training, as described below. After anthropometric measurements, the HR monitoring devices were distributed to the players. A standardized warm-up was conducted by the conditioning coaches of the teams for 10 min, including routine exercises of the players, with back and forth running, change of directions and coordination activities. Next, the players were placed in the starting position and final instructions were given. The test was conducted collectively by a team of qualified instructors, and the players were wearing soccer shoes. Thereby, each instructor carefully monitored three to five players to ensure proper compliance.

Interval Shuttle Run Test (ISRT)

The ISRT was designed to assess the intermittent endurance capacity in team sports. The test has an excellent test-retest reliability (intraclass correlation coefficients – ICCs ≥ 0.91) [25] and has been proved to be valid in relation to criterion measurement of VO_2max determined in a treadmill incremental test (r = 0.70) [26]. The ISRT also showed a *large* association with various performance parameters during field hockey matches, such as the total distance covered (r = 0.61), mean speed (r = 0.62) and HIR (r = 0.54) [27]. Furthermore, the ISRT comprises specific and independent components of the endurance capacity in soccer players, not related to other parameters, such as running economy and lactate thresholds [26].

The ISRT consists of 20-m shuttle and 8-m active recovery periods and was performed as described elsewhere [25]. The players followed the running speed dictated by an acoustic signal until exhaustion. The test started at 10 km/h, increasing by 1 km/h every 90 s and by 0.5 km/h from 13 km/h on. Each 90–second period was divided into two periods of 45 s, comprising 30 s of running and 15 s of walking. The test was terminated if a player could not achieve the required pace during two consecutive shuttles by reaching the line in time. All the players received standard verbal encouragement as motivation during the test. The number of completed shuttles was multiplied by 20 m and the total distance covered was defined as the test performance, which is a common procedure [4–6, 8–13, 26, 28].

Heart rate monitoring

The HR responses during and after the ISRT have been demonstrated to be reliable [25], and its maximum (HRmax) to be equivalent to the peak values verified in other endurance tests [26]. The HR was recorded every 2 seconds during and after the ISRT with chest strap-based team monitoring devices and respective software (Suunto t6, Vantaa, Finland and Acentas, München, Germany). Submaximal HR values at minutes 2, 4, 6 and 9 during the ISRT, HRmax and HRR one minute after the test during active recovery were determined. These parameters are usually considered for HR response analysis during [8–10] and after [24] intermittent testing. The submaximal HR testing points represent running speeds from 11 to 14 km/h in the ISRT, which correspond to other parameters of the endurance capacity, such as lactate thresholds, in female and male soccer players [11, 28]. After exhaustion was reached, the players were required to keep walking along the test distance. Physical exhaustion was verified if a minimum of 95% of the chronological age-predicted HRmax (220 - age) was reached [29]. All HR values were expressed as percentages of the HRmax determined during the test. Only HR records without artefacts or noise were taken into account for analysis and were reported in Table 2 and Table 3.

Statistical analysis

The statistical analyses were carried out with the SPSS software (IBM, version 22.0, USA) and the results were reported as means and standard deviations (SD). All data were normally distributed, as

TABLE 2. Heart rate values of elite and sub-elite female and male soccer players in the Interval Shuttle Run Test (mean ± SD).

HR values	Elite female	Sub-elite female	Elite male	Sub-elite male
n	16	15	16	14
HR 2 min (%)	83 ± 4 *§	88 ± 4 *	74 ± 5	77 ± 4
HR 4 min (%)	89 ± 3 *§	92 ± 3 *	80 ± 5	82 ± 4
HR 6 min (%)	93 ± 3 *§	97 ± 3 *	85 ± 4	86 ± 3
HR 9 min (%)	97 ± 2 *	98 ± 0 [1]	91 ± 4	92 ± 3
HRmax (bpm)	190 ± 6	193 ± 9	191 ± 11	191 ± 8
HRR (%)	83 ± 4	82 ± 4	84 ± 4	82 ± 5

Simple main sex and level effects: p ≤ 0.01; Interaction effect: p ≥ 0.08.

*Significant differences between sexes (p < 0.01). §Significant differences between levels (p < 0.01).

HR: heart rate; HRmax: maximum heart rate; bpm: beats per minute; HRR: heart rate recovery one minute after.

[1]Note: Shown are the mean values of the only 3 sub-elite female players who reached the 9th minute of the test, which were therefore not considered for the statistical analyses. The mean value of the other sub-elite female players at minute 9 after the start of the test was 78 ± 13 %, thus they were already in recovery.

TABLE 3. Pearson's correlation coefficients between the performance in the Interval Shuttle Run Test and the heart rate response of elite and sub-elite female and male soccer players (r / p).

HR response	Elite female	Sub-elite female	Elite male	Sub-elite male
n	16	15	16	14
HR 2 min (%)	- 0.42 / 0.10	- 0.55 / 0.03 *	- 0.41 / 0.11	- 0.18 / 0.54
HR 4 min (%)	- 0.58 / 0.02 *	- 0.59 / 0.02 *	- 0.54 / 0.03 *	- 0.36 / 0.20
HR 6 min (%)	- 0.67 / < 0.01 **	- 0.54 / 0.04 *	- 0.69 / < 0.01 **	- 0.58 / 0.03 *
HR 9 min (%)	- 0.84 / < 0.01 **	-	- 0.78 / < 0.01 **	- 0.78 / < 0.01 **
HRR (%)	0.35 / 0.17	0.27 / 0.33	0.09 / 0.72	0.24 / 0.35

Significance is indicated by * for $p \leq 0.05$ and ** for $p \leq 0.01$.

HR: heart rate; HRR: heart rate recovery one minute after.

verified by the Kolmogorov-Smirnov test (all $p > 0.07$). Sex and competitive level effects were evaluated by a two-way analysis of variance (ANOVA). Differences between competitive playing levels within sexes were analyzed by applying the unpaired t-test. Differences between all groups, as for the anthropometric characteristics, were verified using a one-way ANOVA followed by Bonferroni post-hoc tests. To clarify the meaningfulness, effect sizes (ES) according to Cohen's d were calculated and interpreted as *trivial* (< 0.2), *small* (0.2 to < 0.6), *moderate* (0.6 to < 1.2), *large* (1.2 to < 2.0), *very large* (2.0 to < 4.0), and *extremely large* (≥ 4.0) [30]. Relationships between ISRT performance and HR response were examined using Pearson's correlation coefficient with magnitude thresholds defined as *trivial* (< 0.1), *small* (0.1 to < 0.3), *moderate* (0.3 to < 0.5), *large* (0.5 to < 0.7), *very large* (0.7 to < 0.9), and *extremely large* (≥ 0.9) [30]. The level of statistical significance was set at $p \leq 0.05$.

RESULTS

The performances in the ISRT are shown in Figure 1. The HR responses during the ISRT are displayed in Figure 2 and the HR values are presented in Table 2.

The performance of the female players was lower while the submaximal HR was higher compared with the male players (Figure 1 and Figure 2; Table 2). There was a *large* to *extremely large* sex effect on intermittent endurance performance (ES: 2.12–4.71, $p < 0.01$) and submaximal HR values at minutes 2, 4, 6 and 9 during the ISRT (ES: 1.66–3.40, $p < 0.01$). Specifically, the elite players showed higher performance with reduced submaximal HR values in comparison to their sub-elite counterparts within both sexes (Figure 1 and Figure 2; Table 2). A *large* level effect was evident between the female groups only (ES: 1.22–1.56, $p < 0.01$; male groups – ISRT: ES: 0.40, $p = 0.25$; HR: ES: 0.21–0.60, $p \geq 0.11$).

The HRmax (ES: 0.01–0.43, $p \geq 0.43$) and the HRR (ES: 0.05–0.51, $p \geq 0.18$) did not differ among all groups (Table 2). The correlations between the HRR and the intermittent endurance performance were *trivial* to *moderate* within groups ($r = 0.09–0.35$, $p \geq 0.17$) and *small* when considering all the players pooled ($r = 0.20$, $p = 0.12$). *Large* to *very large* negative correlations were verified between the HR at 6 and 9 min and the intermittent endurance performance for each group ($r = -0.54$ to -0.84, $p \leq 0.04$) (Table 3). However, three out of the 18 elite female players and 13 out of the 16 sub-elite female players did not reach the 9th minute of the test.

DISCUSSION

The aims of the present study were to compare the intermittent endurance performance and the HR response by sex and competitive level in soccer, and the relationships between these parameters. This is the first investigation to analyze such aspects by the same research design and using the ISRT. Our main findings were that (1) there was a *large* to *extremely large* sex effect on performance and submaximal HR values, while a *large* level effect was evident only between the female groups, and (2) the HRR did not differ among all groups and was *trivially* to *moderately* related to the intermittent endurance performance, while the correlations between submaximal HR at 6 and 9 min of the test and the test performance were *large* to *very large* within groups.

Intermittent endurance performance

The first main finding of the study revealed a *large* to *extremely large* sex effect and a *large* level influence within the female players on intermittent endurance performance. Surprisingly, differences were not identified between the competitive playing levels of male players, in contrast to previous studies [3, 7, 8]. Our results are in line with the literature for overall sex differences [11, 12] and competitive level contrasts within female soccer players [9] in intermittent endurance performance.

This was the first study to investigate differences by competitive playing level applying the ISRT within female soccer players. Another investigation with female hockey players from three different competitive levels using this test could not identify any physical-physiological difference among the groups [27]. Indeed, only better dribbling skills in a hockey-specific test discriminated the players by competitive levels [27]. Conversely, intermittent endurance performance was able to explain differences in the final league position of sub-elite female soccer teams [31]. Thus, in women's soccer, the intermittent endurance performance seems to still have a more crucial role.

The intermittent endurance performance of both competitive levels of male players was comparable to that reported for elite players [7, 11, 26] and higher than that observed for university sports players [25]. Based on the outcomes, the intermittent endurance performance is apparently more homogeneous within male soccer players. The high level of the sub-elite male players of the German fourth league may explain this finding, since this result diverges from similar investigations with other groups of players [3, 7, 8]. Possibly, they have reached an optimum of intermittent endurance performance required. In view of this and of previous studies on men's soccer, it seems that currently, technical, tactical, as well as decision making aspects are becoming even more important in determining success in competitions [32, 33].

Altogether, these results demonstrated that the differences in intermittent endurance performance by competitive level are greater in women's soccer (28.4% vs 5.6%, Figure 1). The physical performance alone seems to make still the difference in women's [31], but not in men's soccer considering the main competitions [32, 33]. Soccer coaches and staff should be aware of it and use this in planning and executing their practices when working in each context. The evidence of the discriminative power of the ISRT is still limited and further construct and concurrent validation research in soccer is desirable.

Heart rate response

Concerning the HR response, there was a *large* to *very large* sex effect on the submaximal HR values, while a *large* level effect was only verified between the female groups again. The HRmax and HRR were equivalents among all groups. Nevertheless, sex differences in the submaximal HR response were evident, with female players showing higher values (Figure 2 and Table 2). Each of the HR parameters examined will be specifically discussed below.

Submaximal heart rate

The sex differences in the submaximal HR are in accordance with previous outcomes observed during the incremental test for soccer players [11]. This can be explained by differences in the cardiovascular functions [34] and heart morphology [35] between sexes.

Considering the competitive playing level, the differences between female soccer players were verified for the first time. It may be explained by a different general training status, which results in a lower intermittent endurance capacity, since our sub-elite players have fewer training sessions per week (Table 1). Associations between cumulative training as well as match loads and intermittent endurance capacity during the season have been recently reported in soccer [15] and corroborate our findings.

The slightly higher HR response of the sub-elite male players (Figure 2) did not represent a *large* effect (Table 2), conversely to that reported for male players of the Norwegian first and third leagues [8]. However, in the study of Ingebrigtsten et al. [8], the players of the lower competitive level obtained higher HRmax values ($p < 0.01$), which affects the interpretations. This contrast suggests that male players of the German fourth league may have a higher intermittent endurance capacity.

Overall, these findings showed the practical importance of monitoring the cardiovascular response in soccer players. The differences verified in the submaximal HR response were analogous to those observed in the intermittent endurance performance. Thus, monitoring the HR in the submaximal version of the intermittent test may be a useful and time-efficient approach to verify the intermittent endurance capacity of the players without getting them to perform a maximum effort [15–17]. A reduced submaximal HR during the intermittent field test is associated with positive training adaptations and improved soccer-specific capacity [5, 10, 15]. Taking into account the outcomes discussed before, training interventions combining physical, technical, tactical and/or decision making aspects may be preferable for this purpose.

Maximum heart rate

The HRmax reached by all groups in the ISRT did not differ and was comparable to those values reported for the same [7, 11, 25, 26, 28] and different intermittent field tests [5, 6, 9], as well as for match conditions [6]. Furthermore, considering the mean age of each group and the corresponding mean age-predicted HRmax (220 - age), it was verified that at least 95% of their HRmax was achieved. Thus, the ISRT was able to elicit maximal cardiovascular effort [29] and can be applied for that as a field test in the different groups of soccer players.

Heart rate recovery

One minute after the test, the HR of the players showed equivalent behaviour, returning to about 82% of the HRmax. This outcome is in accordance with values for players when using the ISRT [25], but slightly higher than those reported for male [5] and female [9] soccer players after other intermittent tests, such as the Yo-Yo tests (74–79% of the HRmax). The peculiarities of the tests possibly influence this, since it has been reported that the HRR magnitude is activity-dependent [24].

The differences in the modulation of the autonomic nervous system observed between women and men [19–22] seem to be not reflected in nor detected by HRR measurement immediately after intermittent effort within soccer players. Regardless of some evidence about the use of the HRR as an indicator of training status [23] or its improvement [18], its application in team sports remains questionable [16] and requires more investigation. The HRR after intermittent endurance effort in this study was not consistent evidence for sex and level influences in soccer players.

Relationship between intermittent endurance performance and heart rate response

In the second major finding of our study, the magnitude of the correlations between intermittent endurance performance and HRR, and submaximal HR contrasted. *Trivial* to *moderate* associations were observed for HRR, while *large* to *very large* negative correlations were verified for submaximal HR at 6 and 9 min of the test within groups. This contrast in the magnitude of correlations of both HR parameters with performance has been previously pointed out [16]. This indicates that the submaximal HR measure may be more useful than the HRR when monitoring cardiovascular response in soccer players.

Intermittent endurance performance and heart rate recovery

The *trivial* to *moderate* correlations observed for all groups in this investigation (Table 3) are in line with a previous study [9]. In addition, the HR recovery during each stage of the ISRT was not sex-dependent or related to the test performance (own unpublished observations). Other aspects involved in the intermittent endurance performance with a constant change of directions (shuttles), such as strength, power, and aerobic/anaerobic capacity, seem to play a more important role for the intermittent endurance capacity of soccer players than the HRR after and during the test. Castagna et al. [36] reported, for example, a relationship between the peak power in the countermovement jump and the intermittent endurance performance of male soccer players. Lockie et al. [37] identified *small* relationships among speed/powerful capacities and intermittent endurance performance in female players. Baumgart et al. [28] verified different contributions of endurance capacities to intermittent performance according to sex. The independent character of HR and neuromuscular, metabolic or psychometric parameters as well as their response to training is well-documented [16]. Since intermittent endurance is a relevant physical capacity for match performance [5, 6, 9, 10], it should be improved in soccer players. Thus, it is warranted to further investigate other aspects related to the performance of female and male players in intermittent tests in order to optimize training interventions specifically.

Intermittent endurance performance and submaximal heart rate

The submaximal HR values at 6 and 9 minutes during the ISRT showed the *largest* correlations with the test performance (Table 3). These findings were consistent with results reported in other studies on intermittent testing in soccer players [5, 9, 10]. Especially the HR in the 9th minute, corresponding to the second stage of 14 km/h in the ISRT or 1220 m, negatively correlated for all groups with a *very large* magnitude ($r \leq -0.78$, $p < 0.01$). It was expected, since the longer the test duration, the better (greater distance) the performance. Nevertheless, it must be taken into account that three elite female players did not reach the 9th minute of the test and only three of the sub-elite female players achieved this stage. This particular running speed is associated with the anaerobic thresholds in soccer players and it seems to be more challenging for female players to perform at this metabolic turning point [11, 28].

A similar investigation with elite female soccer players reported a *very large* negative correlation between the performance and the submaximal HR at the 4th minute of an intermittent test ($r = -0.74$, $p < 0.01$) [9]. This was higher than our outcome; however, the *moderate* negative correlation ($r = -0.35$, $p > 0.05$) observed at 2 minutes [9] was in accordance with our study. Interestingly, the *large* negative correlations within the sub-elite female players remained constant, not increasing along the ISRT as observed in the other groups (Table 3). A possible explanation may be the general higher HR values already verified in the initial stages of the ISRT (Table 2), with the players achieving different performances. As a result, the scatter plot would show a more horizontal point cloud, instead of a rising or falling graphical profile. This highlights the need for caution in the generalization of results from studies on one certain population.

Furthermore, submaximal versions of established field tests have been recommended in order to monitor regularly the training status in team sports based on the HR response in a more specific scenario [17]. Specifically, the submaximal HR during the intermittent test is also related to match physical performance in soccer [10], its improvements with cumulative training and match load during the season [15], and has been suggested as the likely most sensitive and realistic HR measure to detect positive training adaptations in endurance of team sports [16]. The ISRT up to a certain stage/time could be applied for this purpose. However, it must be considered that values near or higher than 90% of the HRmax were reached from the 4th minute by female players and from the 9th minute by male players. With this aspect in mind, it seems appropriate to consider these thresholds in order to avoid additional fatigue of the players, especially in the in-season period [15, 16]. Thereby, possible changes in the HRmax of the players should not be neglected.

Limitations and perspectives

In this study the HRmax was used as a reference to monitor the relative effort intensity. The use of the HR reserve (HRmax - resting HR) has been suggested, since it places the players at an equivalent intensity above individual resting levels [38]. Notwithstanding, the measure of HR resting values in the routine of competitive teams is challenging [16]. In addition, combining HRmax and resting HR values would probably reduce the parameter reliability and sensitivity, since the HR reserve incorporates both of them and its reliability still needs direct verification [16, 38]. Thus, further research should investigate the use of other effort intensity indicators and their ecological validity in the specific groups of soccer players. Another aspect is that in our investigation, only intermittent endurance performance and HR response were examined. Other performance, metabolic, neuromuscular and psychometric parameters [16] could be focused on in future similar studies. This will provide a broader understanding of the intermittent performance and how to improve it in soccer players according to sex and level specifically.

Further longitudinal research applying the ISRT to assess its sensitivity to training adaptations, to monitor seasonal variations, as well as to verify its construct and concurrent validity in soccer, as have been done with other intermittent tests [5, 6, 8–10], are also of interest. Finally, minutes 4 and 6 of the ISRT may be considered in future investigations for regular submaximal testing in female and male soccer payers, respectively. These thresholds showed *large* correlations with the test performance, without eliciting cardiovascular exhaustion in the players (Table 2 and Table 3), and comply well with the generally required time to reach an HR steady state [16].

CONCLUSIONS

The gap between competitive levels in female soccer players is greater than that observed for male players in intermittent endurance performance and submaximal HR response. The HRmax as well as the HRR did not differ among groups of elite and sub-elite female and male soccer players in intermittent testing. The ISRT can be applied in elite and sub-elite female and male soccer players as a field test to determine their maximum cardiovascular exhaustion. The HRR had a minor effect on intermittent endurance performance and it was influenced neither by sex nor by level. Submaximal HR values at 6 and 9 min during the ISRT may be considered as thresholds for monitoring procedures in view of the *largest* correlations with the test performance. However, to avoid additional fatigue and higher cardiovascular requirements, minutes 4 and 6 of the test seem more appropriate for female and male players, respectively. Teams' staff and sports scientists should consider these aspects in order to plan and analyze the training, testing and monitoring procedures more specifically according to sex and level in soccer.

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