



A Comparison of Incremental Running Field and Treadmill Tests in Young Soccer Players

by

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The purpose of this study was to compare the incremental running tests performed by young soccer players on a treadmill (Tr) and in the field (FT_{cod}: 100 m change of direction and FT_{cir}: 100 m circle). Nineteen players (average age 17.4 ± 1.1 years; body height 172.0 ± 5.7 cm; body mass 68.9 ± 6.7 kg) volunteered to perform incremental Tr, FT_{cod} and FT_{cir} running tests. In all three tests, players ran for 3 min at 8, 10, 12 and 14 km·h⁻¹ and were given a 1 min rest interval between subsequent stages. Blood lactate concentrations (La) were measured at 1 min rest intervals and the heart rate (HR) responses of players were recorded during the tests. After a 5 min recovery period, the second part of the test started; players ran at 15 km·h⁻¹ with velocity increments of 1 km·h⁻¹ every 1 min until exhaustion. This part was performed to determine maximum HR, maximum La and the players' final velocities. The results showed that players had significantly lower La ($F = 6.93, p = 0.07, \eta^2 = 0.46, 95\%CI_{(TR-FT_{cir})} = -1.91/-0.34, 95\%CI_{(TR-FT_{cod})} = -1.59/-0.05$) and HR ($F = 9.08, p = 0.02, \eta^2 = 0.53, 95\%CI_{(TR-FT_{cir})} = -6.98/-1.68, 95\%CI_{(TR-FT_{cod})} = -7.19/1.08$) responses in the Tr test than in the FT_{cir} and FT_{cod} tests at 14 km·h⁻¹. It was also found that players completed the Tr test ($F = 58.22, p = 0.00, \eta^2 = 0.87$) at higher final running velocities than the FT_{cir} ($95\%CI_{(TR-FT_{cir})} = 1.67/2.78$) and FT_{cod} ($95\%CI_{(TR-FT_{cod})} = 1.69/2.85$) tests. In conclusion, when coaches or sports scientists plan to train at higher running velocities or according to the final velocity in the test, it is advisable to carry out testing in the circumstances under which training will be carried out (in the field or on a treadmill).

Key words: heart rate, running velocity, blood lactate, running tests.

Introduction

Soccer coaching has a particular focus not only on the technical characteristics of soccer players, but also on the development of physical capacities such as muscular strength, speed and endurance (Metaxas et al., 2005). During a match, soccer players cover a total distance of 9.2–12.3 km including 542–1168 m of high speed running and they also perform 11.2 – 23.2 sprints and 553–629 accelerations (Castagna et al., 2017; Ingebrigtsen et al., 2015; Mallo et al., 2015). Therefore, soccer players need a well-developed endurance capacity considering that such short high-intensity movements need to be repeated with comparative quality for the duration of the match, no matter how long distance a player has covered (Stolen et al., 2005). For this reason,

endurance capacity of players is frequently tested by coaches and training programs are being developed to improve it.

Field and laboratory test protocols are used to determine the endurance capacity of players (Jemni et al., 2018). Most of these tests are continuous types, while some of them are interval in nature with short recovery phases (Jemni et al., 2018; Metaxas et al., 2005). A common feature of these tests is that players start at low running velocities which gradually increase. The stages of tests consist of 3–5 min running (Castagna et al., 2010; Kunduracioglu et al., 2007) with 1–2 min recovery intervals in between (Aslan et al., 2012; Castagna et al., 2010; Krstrup et al., 2003). Endurance capacity tests in the laboratory are usually performed on a treadmill as a gold

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standard (Aziz et al., 2005), while field tests are performed using test areas of different shapes, such as a circle (Aslan et al., 2012), shuttle (Castagna et al., 2010b; Ingebrigtsen et al., 2014; Thomas et al., 2016), hexagon (Kunduracioglu et al., 2007) and a 400-m tartan track (Hoppe et al., 2013). During these tests, internal loads (such as maximal oxygen uptake (VO_{2max}), blood lactate concentration (La^-), heart rate response and rating of perceived exertion level values for the running velocity) and external loads (such as final running velocities) are recorded.

Although both field and laboratory tests are used to determine the endurance capacity of players, comparative studies show that there are some differences between field and laboratory test results (Di Michele et al., 2009; Higino et al., 2017; Hoppe et al., 2013; Kunduracioglu et al., 2007). For example, Higino et al. (2017) compared values for VO_{2max} and peak velocity of young soccer players in the field (Shuttle Run Test and Carminatti's Test) and laboratory (Incremental Treadmill Test). They revealed that there were differences in the values of VO_{2max} as determined by the Incremental Treadmill Test and the Shuttle Run Test, as well as lower peak velocities in the Shuttle Run Test compared to peak velocities in the treadmill test and the Carminatti's Test. In another study, Kunduracioglu et al. (2007) compared HR and La^- responses of young soccer players in treadmill and (hexagonal) field tests at fixed running velocity. They reported that HR and La^- responses were higher in the field than in the treadmill test at the same running velocity. Moreover, Metaxas et al. (2005) compared VO_{2max} values of young soccer players in the Yo-Yo field (Yo-Yo Intermittent Endurance test and Yo-Yo Endurance test) and laboratory treadmill tests. They found that the determination of VO_{2max} in soccer players using treadmill exercise tests was more accurate than in the Yo-Yo field tests.

Although laboratory tests to determine endurance capacity provide more accurate results, it seems that field tests are more useful as they include activities similar to training and match conditions (Jemni et al., 2018). However, the number of studies comparing the endurance capacity of players with field and laboratory tests is limited and controversial (Aziz et al., 2005; Higino et al., 2017; Hoppe et al., 2013; Metaxas et al., 2005). To our knowledge, no study has

compared laboratory test results with those of change of direction and circular field tests. Therefore, the aim of this study was to compare the results of laboratory (treadmill) and two different field tests (100 m change of direction and 100 m in a circle) in young soccer players. It was hypothesized that the laboratory test would result in different results for internal and external loads compared to the field tests.

Methods

Participants

Nineteen male young soccer players (average age: 17.6 ± 1.1 years; body mass: 68.9 ± 6.7 kg; body height: 172.0 ± 5.7 cm; training experience: 6.8 ± 1.7 years) voluntarily participated in this study. All players were members of the same youth team competing in a second division team in an elite academy league. Players trained for five days a week, each session lasting for 1.5 h as well as an official match at the weekend.

Written informed consent was obtained from all the participants and their parents. All players and parents were notified regarding the research procedures, requirements, benefits, and risks before giving informed consent. The study was approved by the Pamukkale University Ethics Committee, and was conducted in a manner consistent with the institutional ethical requirements for human experimentation in accordance with the Declaration of Helsinki.

Procedures

All soccer players who participated in the study were firstly measured for body height and mass. Then players were randomly divided into three groups: on the first day one group was chosen to perform the treadmill test while the second group completed the change of direction field test and the third group the circular field test. The groups subsequently performed the other tests with 48-h intervals. Players wore the same shoes for each test. Before each test a 10-min standardized warm up was performed, that consisted of low intensity running, striding, and stretching. All measurements for each player were completed within two weeks during the competitive period. The test protocol used for laboratory and field tests in this study was modified from Castagna et al. (2010a). Validity and feasibility of the test protocol was tested and verified by Castagna et al. (2010a) and Krstrup et

al. (2003). The relative humidity was no more than 50% in the laboratory and the field and the temperature remained between 22.1 and 24.2°C during the tests. The field tests were performed on an artificial grass pitch. The laboratory and field tests were carried out at a similar time of the day in order to have similar chronobiological characteristics (Drust et al., 2005). During the tests, HR responses were recorded. Blood samples (5 µL) were taken from the earlobes of players before tests, after each stage (at velocities of 8, 10, 12, 14 km·h⁻¹) and at the end of the tests. Also, the players' final running velocities were recorded.

Anthropometric Measurements

Players reported to the laboratory at 9 am. On entering the laboratory, body height (cm), and body mass (kg) measurements were taken for each player. Body height was measured using a stadiometer with accuracy to 1 cm (SECA, Germany), while electronic scales (SECA, Germany) accurate to 0.1 kg were used for body mass measurements.

The Laboratory Test

Players completed the laboratory test on a motorized treadmill (Cosmed, Gambettola, Italy). All players were familiar with test protocols and treadmill running technique. The test consisted of two parts. The first part consisted of 3 min stages at 8, 10, 12, and 14 km·h⁻¹ interspersed with 1 min intervals of passive rest. After a 5 min recovery, the second part of the test commenced, in which the players ran at 15 km·h⁻¹ with velocity increments of 1 km·h⁻¹ every 1 min until volitional exhaustion.

Field Tests

The field tests were performed on an artificial grass pitch in two formats: a 100 m run with 180° change of direction (FT_{cod}) and a 100 m circular run (FT_{cir}); the running area was marked with cones placed at 20 m intervals (Figure 1). Like the Tr test, FT_{cod} and FT_{cir} tests were performed in two parts. The first part consisted of 3 min stages at 8, 10, 12, and 14 km·h⁻¹ interspersed with 1-min passive rest intervals. After a 5 min rest interval, the second part started, during which players ran at 15 km·h⁻¹ with velocity increments of 1 km·h⁻¹ every 1 min until volitional exhaustion. The field tests were conducted on windless days so that there was no wind effect on running velocity. During the test, audio beeps from a Conconi-Shuttle Run Timer

(Prospert TMR ESC 1100, Tumer Engineering, Ankara, Turkey) were used to control the running velocity.

Heart Rate Measurement

Each player's heart rate (HR) was recorded at five-second intervals during the laboratory and field tests using short-range radio telemetry (Polar Team Sport System, Polar Electro Oy, Finland). The average HR during the last minute of each stage was taken as the representative HR for that stage. In addition, after the outliers were excluded, the highest HR measurement during the tests was recorded as the maximum HR.

Blood Sampling

Blood samples were taken from the players' ear lobes during the 1 min rest intervals between the running stages. Additionally, blood samples were also taken before players started each test and 3 min after the end of the test. Blood samples were immediately analyzed using portable analyzers (Lactate Plus, Nova Biomedical, Massachusetts, USA) which had been previously calibrated and validated (Tanner et al., 2010).

Statistical Analysis

All results are reported as means (*M*) and standard deviation (*SD*). To assess accuracy and reliability between the laboratory and the 2 field tests, 95% limits of agreement (95% *LOA*), (Bland and Altman, 1986, 1999) and the coefficient of variation (*CV*) (Atkinson and Nevill, 1998) were calculated, respectively. The Bland–Altman method was used to calculate bias and the 95% limits of agreement (*Bias* ± 1.96 × *Sd*). The 95% limits include 95% of the difference between the two measurement methods used (Myles and Cui, 2007). The *CV* value (<10%) was calculated in accordance with Atkinson and Nevill (1998). A one-way analysis of variance for repeated measurements was used to determine differences between the laboratory and the 2 field tests. Before using parametric tests, the assumption of normality was verified using the Shapiro-Wilk test (*p* > 0.05). Effect-Size Correlations (*ES*) were calculated to determine practical differences (η^2 , where <0.1, 0.1, 0.3, and 0.5 represent trivial, small, medium, and large *ES*, respectively; Cohen, 1988). Also, 95%*CI* was calculated for the difference between mean values for each of the estimated variables. The Bonferroni Post Hoc test

was applied to make pairwise comparisons between the laboratory and the 2 field tests. The level of statistical significance was set at $p < 0.05$.

Results

The means (\pm SD), CV (%) and 95% LOA values for blood lactate responses (mmol) for the first parts of the Tr, FT_{cir} and FT_{cod} tests are presented in Table 1. For the blood lactate responses at 12 km·h⁻¹ and 14 km·h⁻¹, the 95% LOA values suggest an underestimation of the Tr test compared to both FT_{cir} (by 0.3 ± 1.7 and 1.2 ± 2.6 , respectively) and FT_{cod} (by 0.3 ± 2.0 and 0.8 ± 2.4 , respectively); the same results were recorded for the maximum blood lactate responses, which differed by 0.7 ± 4.0 for Tr versus FT_{cir} and by 0.7 ± 4.3 for Tr versus FT_{cod}. The intermeasurement CV values for Tr and FT_{cir} test blood lactate responses ranged from 18.3 to 44.6%, while those for the Tr and FT_{cod} tests ranged between 19.6 and 51.8%. The only statistically significant differences for blood lactate responses were found for tests at 14 km·h⁻¹ ($F = 6.93$, $p = 0.07$, $\eta^2 = 0.46$, η^2 represents medium magnitude of change) between the Tr and FT_{cir} tests (1.2 ± 2.6 ; $95\%CI_{(Tr-FT_{cir})} = -1.91/-0.34$) and

between the Tr and FT_{cod} tests (0.8 ± 2.4 ; $95\%CI_{(Tr-FT_{cod})} = -1.59/-0.05$). The *post hoc* analyses confirmed that the blood lactate responses tested by FT_{cir} and FT_{cod} were higher than the responses during the Tr test at 14 km·h⁻¹ running velocity.

Table 2 displays *mean* (\pm SD), CV (%) and 95% LOA values for HR and HR_{max} responses (bpm) for all participants to the first part of the Tr, FT_{cir} and FT_{cod} tests. HR values obtained during the Tr (135.5 ± 10.5), FT_{cir} (135.8 ± 12.6) and FT_{cod} (134.9 ± 11.6) tests were very similar at the slowest velocity (8 km·h⁻¹), whereas at 10, 12, and 14 km·h⁻¹, the 95% LOA showed an underestimation of the Tr test compared to both FT_{cir} (by 1.0 ± 14.5 , 2.8 ± 11.2 , and 4.4 ± 8.0 , respectively) and FT_{cod} (by 0.5 ± 21.1 , 1.8 ± 19.0 , and 3.0 ± 12.9 , respectively). Furthermore, the maximum HR responses tended to be lower in the FT_{cir} (193.7 ± 8.6) and FT_{cod} (194.57 ± 7.8) tests compared to the Tr test (197.2 ± 7.1). For this finding, *ES* presented large magnitude of change ($\eta^2 = 0.52$) according to Cohen's thresholds, and CV values for HR responses between Tr and FT_{cir} tests (CV = 1.9 - 3.5%) and between Tr and FT_{cod} tests (CV = 1.4 - 5.3%) were low.

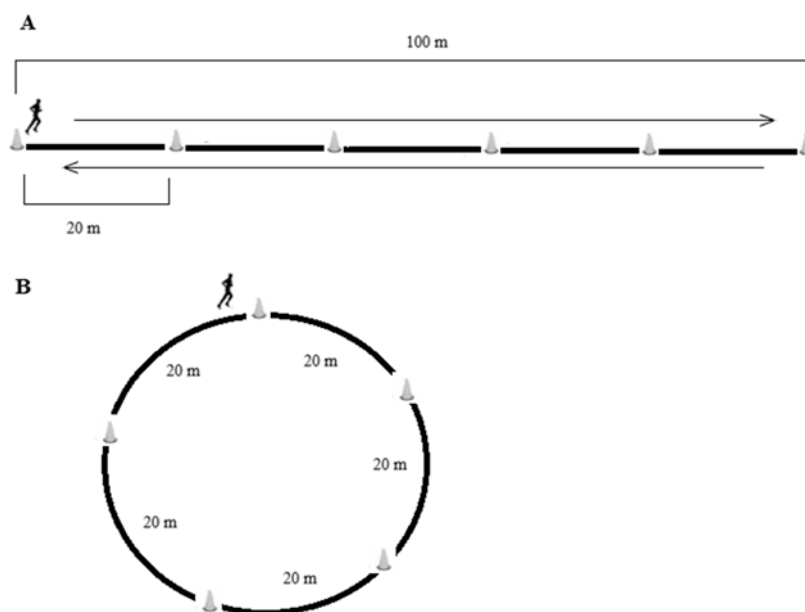


Figure 1

Schematic designs of the tracks marked out for the field tests. A: field test with 180° change of direction; B: circular field test

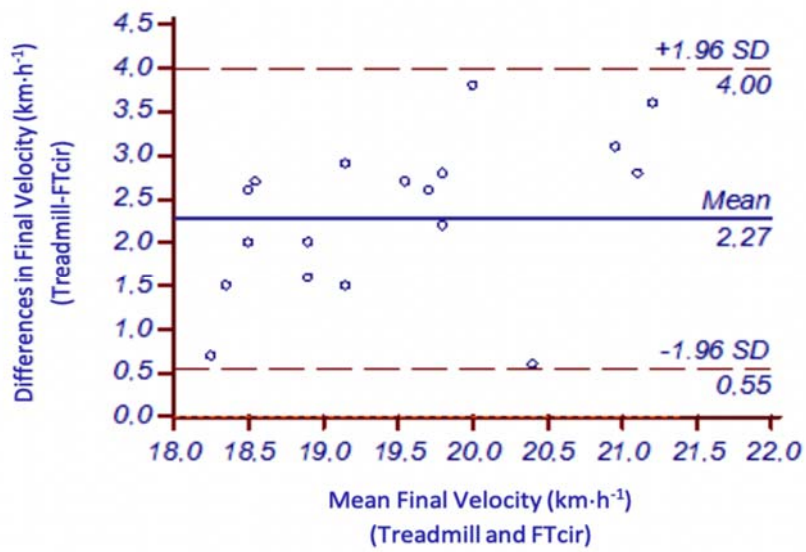


Figure 2
*Bland-Altman plots for Treadmill and FT_{cir} (circular field test)
 mean differences in final velocity (km·h⁻¹)*

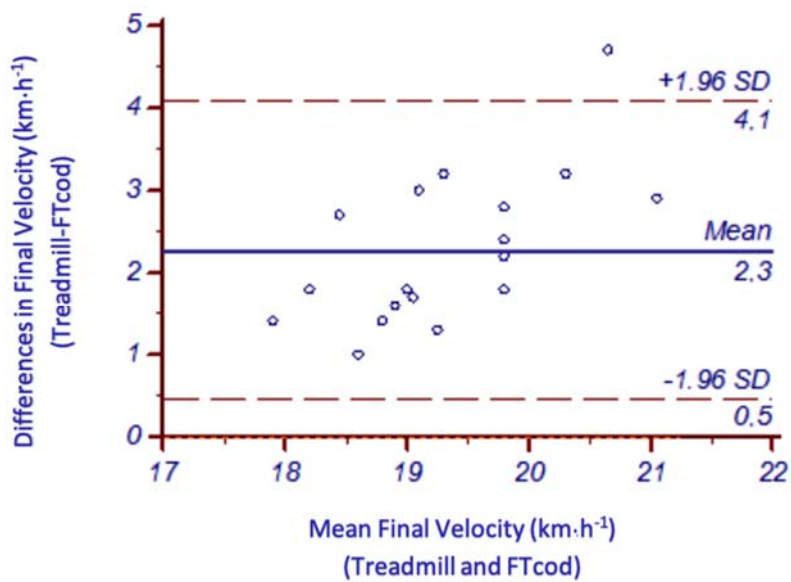


Figure 3
*Bland-Altman plots for Treadmill and FT_{cod} (field test with change of direction)
 mean differences in final velocity (km·h⁻¹)*

Table 1
Comparison of blood lactate responses (mmol) at different running velocities between laboratory and field tests

	Tr	FT _{cir}	FT _{cod}	ES	MoC	Tr / FT _{cir}		Tr/ FT _{cod}	
						CV (%)	95%LOA (Bias±1.96xSd)	CV (%)	95%LOA (Bias±1.96xSd)
Resting	1.4 ± 0.3	1.3 ± 0.9	1.3 ± 0.7	0.01	Trivial	44.6	0.07 ± 1.7	36.4	0.08 ± 1.3
8 km·h ⁻¹	1.5 ± 0.5	1.6 ± 0.6	1.5 ± 0.5	0.04	Trivial	34.8	0.1 ± 1.4	35.5	0.01 ± 1.4
10 km·h ⁻¹	1.6 ± 0.4	1.6 ± 0.5	1.7 ± 0.9	0.02	Trivial	21.6	0.01 ± 0.9	34.0	0.1 ± 1.5
12 km·h ⁻¹	2.2 ± 0.7	2.5 ± 0.9	2.5 ± 1.2	0.14	Small	27.6	0.3 ± 1.7	31.6	0.3 ± 2.0
14 km·h ⁻¹	3.4 ± 1.0	4.5 ± 1.6*	4.2 ± 1.4*	0.46	Mediu m	32.9	1.2 ± 2.6	51.8	0.8 ± 2.4
Maximum	7.9 ± 1.8	8.5 ± 1.8	8.6 ± 2.5	0.14	Small	18.3	0.7 ± 4.0	19.6	0.7 ± 4.3

ES = Effect Size; MoC: Magnitude of Change; CV = Coefficient of Variation; 95% LOA = 95% Limits of Agreement; *significant difference from treadmill test (p < 0.05); Tr =Treadmill; FT_{cir} = Circular field test; FT_{cod} = Field test with change of direction.

Table 2
Comparison of heart rate responses (bpm) at different running velocities between laboratory and field tests

	Tr	FT _{cir}	FT _{cod}	ES	MoC	Tr / FT _{cir}		Tr / FT _{cod}	
						CV (%)	95%LOA (Bias ± 1.96xSd)	CV (%)	95%LOA (Bias ± 1.96xSd)
8 km·h ⁻¹	135.5 ± 10.5	135.8 ± 12.6	134.9 ± 11.6	0.01	Trivial	3.5	0.3 ± 13.7	5.3	0.6 ± 20.3
	151.6 ± 10.8	152.3 ± 11.8	152.2 ± 13.2	0.05	Trivial	3.3	1.0 ± 14.5	4.9	0.5 ± 21.1
10 km·h ⁻¹	166.9 ± 10.1	168.7 ± 10.7	168.7 ± 12.5	0.21	Small	2.6	2.8 ± 11.2	4.0	1.8 ± 19.0
12 km·h ⁻¹	178.6 ± 8.7	182.9 ± 10.1*	181.7 ± 10.9*	0.53	Large	2.34	4.4 ± 8.0	2.7	3.0 ± 12.9
14 km·h ⁻¹	197.2 ± 7.1	193.7 ± 8.6	194.57 ± 7.8	0.52	Large	1.90	3.5 ± 7.8	1.4	2.6 ± 5.7

ES = Effect Size; MoC: Magnitude of Change; CV = Coefficient of Variation; 95% LOA = 95% Limits of Agreement; *significant difference from treadmill test (p < 0.05); Tr =Treadmill; FT_{cir} = Circular field test; FT_{cod} = Field test with change of direction.

Table 3
Comparison of the final velocities (km·h⁻¹) between laboratory and field tests

Final Velocity	Tr	FT _{cir}	FT _{cod}	ES	MoC	Tr / FT _{cir}		Tr / FT _{cod}	
						CV (%)	95%LOA (Bias ± 1.96xSd)	CV (%)	95%LOA (Bias±1.96xSd)
	20.5 ± 1.2	18.2 ± 0.8*	18.2 ± 0.6*	0.87	Large	8.8	2.2 ± 1.7	8.9	2.2 ± 1.8

ES = Effect Size; MoC: Magnitude of Change; CV = Coefficient of Variation; 95% LOA = 95% Limits of Agreement; *significantly difference from treadmill test (p < 0.05); Tr =Treadmill; FT_{cir} = Circular field test; FT_{cod} = Field test with change of direction.

As the prominent results, HR responses were significantly lower ($F = 9.08$, $p = 0.02$, $\eta^2 = 0.53$, η^2 represents large magnitude of change) in the Tr test (178.6 ± 8.7) compared with both FT_{cir} (4.4 ± 8.0 ; $95\%CI_{(Tr-FT_{cir})} = -6.98/-1.68$) and FT_{cod} (3.0 ± 12.9 ; $95\%CI_{(Tr-FT_{cod})} = -7.19/1.08$) tests at $14 \text{ km}\cdot\text{h}^{-1}$ running velocity.

Table 3 shows that mean differences in final velocity between Tr and FT_{cir} tests (2.2 ± 1.7 , $95\%CI_{(Tr-FT_{cir})} = 1.67/2.78$) and between Tr and FT_{cod} tests (2.2 ± 1.8 , $95\%CI_{(Tr-FT_{cod})} = 1.69/2.85$) were significant ($F = 58.22$, $p = 0.00$, $\eta^2 = 0.87$, η^2 represents large magnitude of change). The 95% LOA revealed overestimation of the Tr test against both FT_{cir} and FT_{cod} (Figures 2 and 3). Low CV values were also found for final velocities when comparing Tr and FT_{cir} tests ($CV = 8.8\%$) and Tr and FT_{cod} tests ($CV = 8.9\%$).

Discussion

Players need a well-developed endurance capacity to be able to perform effectively in soccer. For this reason, coaches often test the endurance capacity of players either in the laboratory or in the field. While it is possible to standardize humidity, temperature, wind and other environmental conditions in laboratory tests, field tests allow coaches to test players under competition and training conditions. During the tests, players' aerobic power, anaerobic threshold running velocity and heart rate are determined and training programs are prepared on the basis of the results. In order to achieve the targeted development following training, players must train with appropriate loads. If there are differences between the laboratory and field tests in terms of physiological responses and final velocities, this may cause players to train with inappropriate loads. Therefore, the aim of the current study was to compare physiological responses to, and final velocities achieved in, an incremental running test performed with an identical protocol under Tr, FT_{cir} and FT_{cod} conditions. The most important finding of the study is that there were differences among the Tr, FT_{cir} and FT_{cod} tests in terms of the heart rate, blood lactate responses and final velocities in young soccer players.

It is very important to determine the heart rate and blood lactate responses at fixed running velocities during the field and laboratory tests for

the optimal planning of players' endurance training. This study found no significant differences in the heart rate and blood lactate responses of young soccer players running at 8, 10, and $12 \text{ km}\cdot\text{h}^{-1}$ across the Tr, FT_{cir} and FT_{cod} tests. These results show that players register similar physiological responses to treadmill and field tests that can be thus used interchangeably at low running speeds. These results are in line with those of Kunduracioglu et al. (2007) who reported no significant differences in HR and La- responses between (hexagonal) field tests and Tr tests at 8, 10, and $12 \text{ km}\cdot\text{h}^{-1}$ running velocities. The results of the current study also show no significant differences between the Tr, FT_{cir} and FT_{cod} tests in terms of the HR_{max} and maximum La- values of the players, which indicated that players reached their maximum effort during Tr, FT_{cir} and FT_{cod} tests. These findings are in-line with previous studies (Bradley et al., 2011; Hoppe et al., 2013; Metaxas et al., 2005).

On the other hand, while in the field and treadmill tests players showed similar HR and La- responses at low running velocities, when running at the velocity of $14 \text{ km}\cdot\text{h}^{-1}$ they showed lower HR and La- responses in the Tr test compared to the two field tests. In addition, players in the Tr tests achieved higher final velocities than in the field tests. Bland-Altman plots of final velocities also indicated higher values for the Tr test compared to the FT_{cir} and FT_{cod} tests. One reason for why players showed similar HR and La- responses at low running velocities yet lower responses in the Tr test at higher running velocities could be the lack of air resistance in the Tr test results and lower energy consumption (Jones and Doust, 1996). This higher energy consumption may then cause fatigue at higher running velocities in the field tests. Findings of Higino et al. (2017) were partially similar to those of our study as they reported that players in the treadmill test showed higher peak velocities than the shuttle run field test, however, showed similar peak velocities in the Carminatti's field test.

The Bland-Altman approach was used to quantify both Tr vs. FT_{cir} and Tr vs. FT_{cod} agreement in estimating HR and La- responses and final velocity. As shown in Tables 1, 2 and 3, there are strong agreements between laboratory and field measurements, and this may be

interpreted as evidence supporting the interchangeability of these tests.

A limitation of this study is that HR and La- measurements were not made for velocities over 14 km·h⁻¹. The reason for this is that in the second part of the test protocol there was a continuous velocity increase of 1 km·h⁻¹ per min from 15 km·h⁻¹ in order to determine the final running velocity. Thus, in future studies, researchers should examine HR and La- responses to field and laboratory tests at velocities of up to 15 km·h⁻¹.

In conclusion, coaches and sports scientists may choose either treadmill or field tests if they aim to determine the maximum HR and maximum La- of players. However, especially when coaches or sports scientists plan to train at

higher running velocities or according to the final velocity in the test, it is advisable to carry out testing under the same conditions where training is to be carried out (in the field or on a treadmill). This study also indicates that variations in the field test protocol (change of direction vs. circle) do not cause significant differences in terms of internal and external loads. This suggests that coaches and sports scientists can use 100 m circular or 100 m change of direction running protocols in field tests. On the other hand, FTcod test may be preferred to determine and monitor the endurance capacity of players during the whole season due to the fact that FTcod includes soccer-specific movements (i.e., direction change, acceleration and deceleration).

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