ORIGINAL ARTICLE

TRENDS in
Sport Sciences
2023; 30(**4**): 143-155
ISSN 2299-9590
DOI: 10.23829/TSS.2023.30.4-2

Correlation between performance in repeated sprints and performance in other laboratory and field fitness tests in female soccer athletes

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Abstract
Introduction. The ability to perform repeated sprints is one of the most important physical abilities in soccer. Aim of Study. The aim of this study was to examine the relationship between the ability to perform repeated sprints (6 × 20 m in a 15-s cycle) in female soccer players from two different age groups, with aerobic capacity (YYIR1), jumping ability (single-leg hop test), isokinetic strength (60°/s, 180°/s, 300°/s), speed performance (S10-m and S30-m), and change of direction ability (505 COD test). The second objective of the study was to compare the performances of the two different groups in the tests. Material and Methods. Twenty-four female soccer players from Greece participated in this study and they were divided into two groups: (i) U-16 (division II) female soccer athletes (age: 15.8 ± 0.8 years, height: 160.5 ± 5.1 cm, body mass: 59.4 ± 7 kg), and (ii) adult female (division I) soccer athletes (age: 21.9 ± 4.1 years, height: 165.7 ± 6.1 cm, body mass: 62.2 ± 7.5 kg). The Pearson correlation coefficient and t-test for independent samples were used for statistical analysis. Results. The S10-m, S30-m and single-leg hop tests appeared to be the variables most associated with the total time in the RSA test in U-16 female soccer players. S10-m and the change of direction ability appeared to be the variables most associated with the total time in the RSA test in adult female players. Conclusions. It seems that U-16 Greek female soccer players do not differ from adults in most of the physical fitness tests conducted in the field and laboratory.

KEYWORDS: women, soccer, physical fitness tests, repeated sprint ability.

Received: 13 September 2023
Accepted: 29 October 2023

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Introduction

Women's soccer has been developing rapidly in recent years, and the Fédération Internationale de Football Association (FIFA) has set a goal for the number of women soccer athletes worldwide to reach 60 million by 2026 [52]. During a women's soccer match, each player covers a total distance of 8.5-11 km, of which 1.5-1.8 km are high-intensity running and 14.9-460 m are sprints [11, 36, 37]. High-intensity actions are typically crucial for the outcome of a game, as they are associated with the attacking phase and goal-scoring opportunities [10, 16, 42]. Repeated high-speed actions consisting of two or more sprints with less than 20 s of recovery between efforts occur approximately 31-33 times during international match play [9, 19]. Repeated sprint ability (RSA) has been defined in the literature as short sprints, typically less than 10 s in duration with recovery periods of 60 s or less [3].

RSA can be influenced by both aerobic and anaerobic metabolism [5]. However, the relationship between aerobic and anaerobic variables and an athlete's ability to repeat sprints is uncertain, as it depends on the test used to assess RSA [4, 50]. From a physiological perspective, RSA is a complex quality that is correlated with motor unit activation and is essential to achieving maximal sprint speed and oxidate capacity for phosphocreatine (PCr) recovery and hydrogen (H+) buffering to provide the ability to repeat sprints [7]. Additionally, the power and strength of the lower limbs assist in acceleration and achieving maximum speed in the initial repetitions, while aerobic capacity helps sustain performance in the final sprints [34]. Performance in RSA could also depend on the player's agility, as agility has been correlated with straight-line sprinting [6]. It is important to understand which physical capacities impact RSA, as such knowledge may help coaches define better strategies for improving RSA [22].

In another recent study [22] conducted on female soccer players from Division I in Portugal, positive moderate correlations were observed between peak minimum RSA and adductor and abductor strength. Positive moderate correlations were also found between peak maximum RSA and adductor and abductor strength. Lastly, a moderate negative correlation was found between fatigue index in RSA and Yo-Yo intermittent recovery test level 1 (YYIR1 test) performance. In another study involving female collegiate soccer players in Division I, a correlation was found between RSA total time (RSATT) and time in the 10-m ($r = 0.50$) and 30-m $r = 0.71$) sprints, as well as the left leg in the agility test ($r = 0.57$) [32]. The percentage change in sprint time from the first to the last sprint in the RSA test was correlated only with the left leg in the agility test ($r = 0.53$) in the same study. Among Norwegian female soccer players from Division II, marked correlations were observed between various parameters of the RSA test and the total distance covered in an aerobic capacity assessment test. Specifically, there were significant negative correlations between the fastest time ($r = –0.483$, $p \leq 0.01$), total time ($r = –0.552$, $p \leq 0.01$), and mean time ($r = –0.552$, $p \leq 0.01$) recorded during the RSA test and the total distance covered in the aerobic capacity assessment test [46].

Furthermore, linear sprint over 40 m had a strong relationship with RSA fastest time, RSA mean time, and RSATT. In a study involving Brazilian female soccer athletes, negative correlations were observed between high-intensity exercise tolerance and the RSA performance decline, as well as oxygen uptake and overall RSA performance (e.g., RSAbest and RSAmean) [2]. Finally, in a group of 25 elite-level female athletes from Ireland, performance in an endurance test was negatively correlated with RSATT ($r = –0.58$, $P = 0.002$), and RSA first sprint time (RSAT1) was negatively correlated with endurance performance ($r = –0.58$, $P = 0.03$) [12]. The same study also found a correlation between 10-m sprint time ($r = 0.78$, $P = 0.0001$) and 20-m sprint time ($r = 0.89$, $P = 0.0001$) with RSATT, as well as a correlation between 30-m sprint time ($r = 0.92$, $P = 0.0001$) and RSAT1 ($r = 0.92$, $P = 0.0001$) with RSATT.

However, of these studies, only two [12, 32] used similar tests to assess RSA so that their results could be compared. Furthermore, regarding the evaluation of aerobic capacity, there is greater consensus among the studies, as three [12, 22, 32] used the same test. The same applies to speed, as most studies use similar distances [12, 22, 32, 46]. Additionally, studies that assess change of direction ability use different tests [1, 22, 32, 46], and those that study lower limb strength apply different methods and tools [22, 32, 46]. Furthermore, studies that examine vertical jump ability use bilateral jumps [22, 32, 46], and the available literature reports no study that has examined the correlations between variables from the RSA test and single-leg broad jump (SBJ) in female soccer players. In view of the above, it is not possible to make comparisons between the studies. In the present study on female soccer athletes, a potential correlation of RSA test performance with female athletes' performance on tests of speed, agility, strength, aerobic capacity and jumping ability was investigated. It was also verified whether age (adult female vs pubertal girls) affected these results. It needs to be mentioned that to the best of our knowledge there is no research in the literature that examines the existence of correlations between the RSA test and various laboratory and field fitness tests for U-16 female soccer players. The aim of this study was to examine the relationship between RSA and aerobic capacity, jump ability, isokinetic strength, speed performance, and change of direction (COD) ability in female soccer athletes from two different age groups. The second aim of the study was to compare the performance of the two different age groups in field and laboratory tests. It was hypothesized that athletes with better performance in the RSA test would also have better performance in the fitness tests in both field and laboratory settings. Specifically, it was hypothesized that stronger correlations would exist between aerobic capacity and all variables from the RSA test, as well as between sprint times at 10 and 30 m and the RSATT. Additionally, it was hypothesized that there would be differences in performance across all the tests between the two age groups.

Material and Methods

Design

The measurements were conducted over a two-day period during the competitive season. The measurements took place at the Laboratory of Evaluation of Human Biological Performance at the Department of Physical Education and Sport Science of the Aristotle University of Thessaloniki, as well as on the field on artificial turf. Before the assessment of muscle strength in the laboratory, the athletes performed a 5-min warm-up on a static bicycle (Monark 839, Vansbro, Sweden) at 60 W [15]. Subsequently, they performed dynamic stretches of the knee flexor and extensor muscles. Before the field measurements, the athletes followed a warm-up relevant to the tests to be performed for 10 min (a variation of FIFA 11+ and dynamic lower limb stretches). Additionally, the athletes had a familiarization session with the tests on a different day before participating in the field measurements. Finally, the athletes were advised to avoid alcohol and caffeine consumption in the last 24 hours [28] and to have their last meal at least 3 hours before their visit to the laboratory or the field.

- Day 1: In the laboratory, body weight and height were measured, body fat was assessed using the skinfold method, and subsequently, muscle strength was evaluated using an isokinetic dynamometer. Then, on the field, the RSA was assessed.
- Day 2: Single-leg horizontal jump ability, speed, agility, and aerobic capacity were measured.

Subjects

The study involved 24 female (semi-professional and youth) soccer athletes from divisions I and II of Greece, who were divided into two groups: (i) U-16 (division II) female soccer athletes (age: M = 15.8, SD = 0.8 years, height: M = 160.5, SD = 5.1 cm, body mass: M = 59.4, SD = 7 kg, % body fat: M = 27.6, SD = 4.7, training age: 8.2, SD = 1.7 years), and (ii) adult female (division I) soccer athletes (age: M = 21.9, SD = 4.1 years, height: M = 165.7, SD = 6.1 cm, body mass: M = 62.2, SD = 7.5 kg, % body fat: M = 28, SD = 0.04, training age: 10.8, SD = 2.6 years). All the athletes had at least three years of participation in competitions and followed strength training programs during the current competitive season, with a frequency of one to two times per week. In total, they participated in three to four training sessions and one match per week. The athletes had no injuries in the two months prior to their participation in the measurements. The participants in the study were informed about the benefits and possible risks. Before the data collection, all the participants were informed about the research, they signed their written consent, and were free to withdraw from the study at any time. For participants under 18 years of age, consent was obtained from their parent or guardian. The research ethics committee of the Department of Physical Education and Sport Science in Serres at the Aristotle University of Thessaloniki approved the conduct of the research.

Anthropometric measurements

The measurements of stature and body mass were taken using an electronic digital scale (Seca 220e, Hamburg, Germany) (ICC = 1) [38]. The percentage of body fat was calculated based on the sum of four skinfold measurements (biceps, triceps, subscapular, and suprailiac). Skinfold thickness was measured using a Lafayette skinfold caliper (Lafayette, Ins. Co., Indiana) on the right side of the body [48]. Body density was estimated according to the equations of Durnin and Rahaman [14], while the percentage of body fat was estimated using the Siri equation [47].

Repeated sprint ability

For the assessment of repeated sprint ability, the protocol designed by Gabbett [18] for elite-level female soccer players was used (Figure 1A). This test has been shown to be a valid and reliable assessment of RSA in elite female soccer players (ICC = 0.91, TE = 1.5%) [18]. Players performed 6 × 20-m maximal effort sprints on a 15-s cycle. Upon the completion of each timed 20-m sprint, players performed a 10-m deceleration followed by a 10-m active recovery jog back to the next start line before coming to a complete standstill prior to the next sprint [18]. Athletes began each sprint 0.5 m behind the photocell gate (Microgate, Bolzano, Italy), and sprint performance was recorded at a frequency of 0.01 s. The researcher recorded the active recovery period between 20-m sprints using a stopwatch (AMILA, Thessaloniki, Greece), and athletes were informed about this. The variables calculated in the RSA test were:

- RSATT = the sum of all six 20-m sprint times stated in seconds [18];
- FI = the decrease in sprint performance from the first to the last sprint was calculated and presented as a percentage. The following equation was used [18]:

$$Fatigue\ Index = 100 \times \frac{(Sprint_{best} - Sprint_{worst})}{Sprint_{best}}$$

- Sdec% = sprint decrement (%) calculates fatigue by comparing the actual performance against the

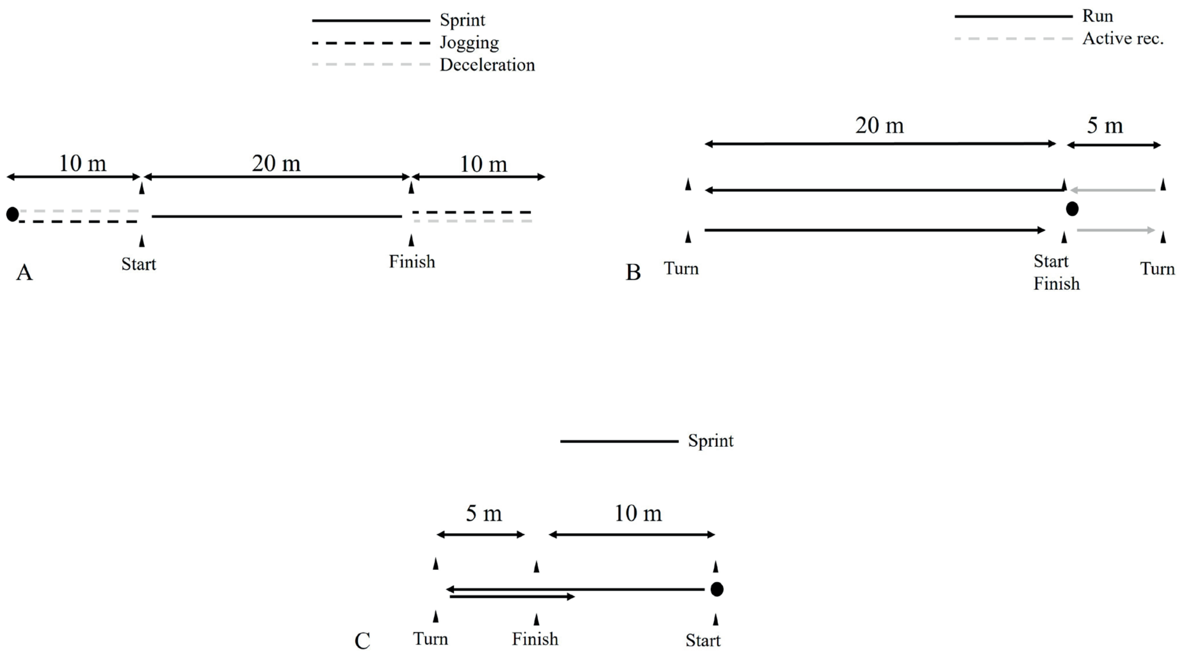


Figure 1. Descriptions of: A. RSA test; B. YYIR1 test; C. 505 COD test

ideal performance (i.e., should the best 20-m effort be replicated in each of the six repetitions). The following equation was used [21]:

$$\textit{Sprint decrement}\ (\%) = \{(S1 + S2 + S3 + S4 + S5 + S6 / S_{best} \times 6) - 1\} \times 100$$

Aerobic capacity
The subjects completed the YYIR1 test as described by Krustrup et al. [30], which has been deemed to be a reliable assessment of aerobic endurance [23]. The test was performed using an audio recording. Each athlete performed repeated 20-m shuttle runs at increasing velocities with 10 s of active recovery. During the active recovery, participants walked around a marker placed 5 m behind the finishing line (Figure 1B). An individual's test was terminated when the subject failed to reach the starting line within the allotted time period on two occasions or the participant felt unable to complete another shuttle at the assigned speed. The total distance covered by a subject was used as a performance measure.

Agility
For the assessment of agility, the 505 COD test (Figure 1C) was used, as described in various studies [33]. Subjects used a standing start with the same body position as per the sprints. They then sprinted through the photocell gate (Microgate, Bolzano, Italy), planted one foot at the point where they had to make a 180° turn, and sprinted again through the photocell gate. A trial attempt was performed for each leg, followed by two more attempts that were recorded. There was a 90-s break between the two attempts, and the fastest attempt was used for analysis. The ICC for the measurement was ICC = 0.88.

Isokinetic strength
The isokinetic strength of the knee flexor and extensor muscles in both legs was assessed using an isokinetic dynamometer (CSMI, Humac Norm Testing & Rehabilitation System, Stoughton, MA, USA). The maximum isokinetic strength was recorded as the torque of the knee flexor and extensor muscles for every 5° throughout the range of motion in the concentric phase. Participants were evaluated at angular velocities of 60°/s, 180°/s, and 300°/s [13]. Three trials were performed for each leg at each angular velocity, with a 40-s rest between the three trials at the different angular velocities. Prior to recording the maximum torque of the knee flexor and extensor muscles, participants performed three practice trials at each angular velocity for each leg.

Jumping ability
The single-leg broad jump test: the athletes, supported only on the jumping leg and with their hands on their hips, stood behind the starting line. They were instructed

to jump as far as they could and land on the same leg. Participants were asked to maintain their position for 2 to 3 s upon landing; otherwise, the attempt was considered invalid and had to be repeated [38]. The distance from the starting line to the athlete's heel was defined as the jumping distance and measured using a tape measure [39]. Before recording the jumps, the athletes performed a trial attempt with each leg. Two jumps were executed for each leg with a 30-s rest between them, and the best jump was used for analysis.

Linear speed

Linear speed was evaluated at 10 and 30 m using photocells (Microgate, Bolzano, Italy), which have been deemed reliable for assessing speed in female soccer athletes [35]. Participants started 0.5 m behind the initial timing gate in a 2-point split stance and were instructed to set off in their own time and run maximally to a marker placed 2 m beyond the 30-m timing gate. Each subject performed two sub-maximum effort sprints prior to three maximal effort sprints, separated with a minimum of 2 min of rest, but no longer than 3 min. Times were recorded to the nearest 0.01 with the fastest time of the three efforts at 10-m, 20-m, and 30-m used for analysis.

Statistics

The data were presented as mean ± standard deviation. The normality of the data was confirmed using the 1-sample Kolmogorov–Smirnov test. Based on the results it was determined that a non-parametric test was not necessary. Additionally, for the physical fitness variables their confidence intervals (95%) and the coefficient of variation were reported. To explore possible correlations between RSA (RSATT, FI, Sdec%) and other variables (strength, jump ability, speed, agility, aerobic endurance), the Pearson correlation coefficient was used. The strength of the correlation was determined based on the value of r: $r \leq 0.1$, trivial; $0.1 < r \leq 0.3$, small; $0.3 < r \leq 0.5$, medium; $0.5 < r \leq 0.7$, large; $0.7 < r \leq 0.9$, very large; and $r > 0.9$, almost perfect [26]. To compare the two age groups, an independent sample t-test was used. The significance level was set at $p \leq 0.05$. The SPSS software (version 25.0, SPSS Inc., Chicago, IL) was used for all the analyses.

Results

Comparison between the two age groups

The results of the statistical analysis for the strength of the knee flexor muscles of the right leg at 180°/s showed significant differences between the two groups ($t = –2.772$, $p = 0.012$, Cohen's $d = –1.19$, CI: –18.26-–2.58) (Figure 2E). Additionally, the results of the statistical analysis for the strength of the knee flexor muscles of the right leg at 300°/s indicated significant differences between the two groups ($t = –2.659$, $p = 0.015$, Cohen's $d = –1.14$, CI: –20.17-–2.44) (Figure 2F). For the remaining variables, no differences were found between the two groups (Figure 2). For the deficit between the two legs in the strength of the knee extensor muscles at 60°/s significant differences were also recorded between the groups ($t = –2.678$, $p = 0.014$, Cohen's $d = –1.15$, CI: –13.55-–1.68) (Figure 3A).

Correlations in the U-16 group of female soccer athletes

The results of the statistical analysis showed a large positive correlation ($r = 0.608$, $p = 0.036$) between RSATT and S10-m, a very large positive correlation ($r = 0.883$, $p < 0.001$) between RSATT and S30-m, a large negative correlation ($r = –0.631$, $p = 0.028$) between RSATT and SBJ right, a large negative correlation ($r = –0.694$, $p = 0.012$) between RSATT and SBJ left, a very large negative correlation ($r = –0.744$, $p = 0.006$) between FI and Flex def 60°/s, a large positive correlation ($r = 0.607$, $p = 0.036$) between FI and L Ratio F/E 60°/s, a large positive correlation ($r = 0.627$, $p = 0.029$) between Sdec% and Flex def 60°/s and a large positive correlation ($r = 0.584$, $p = 0.046$) between FI and L Flex 180°/s (Table 1).

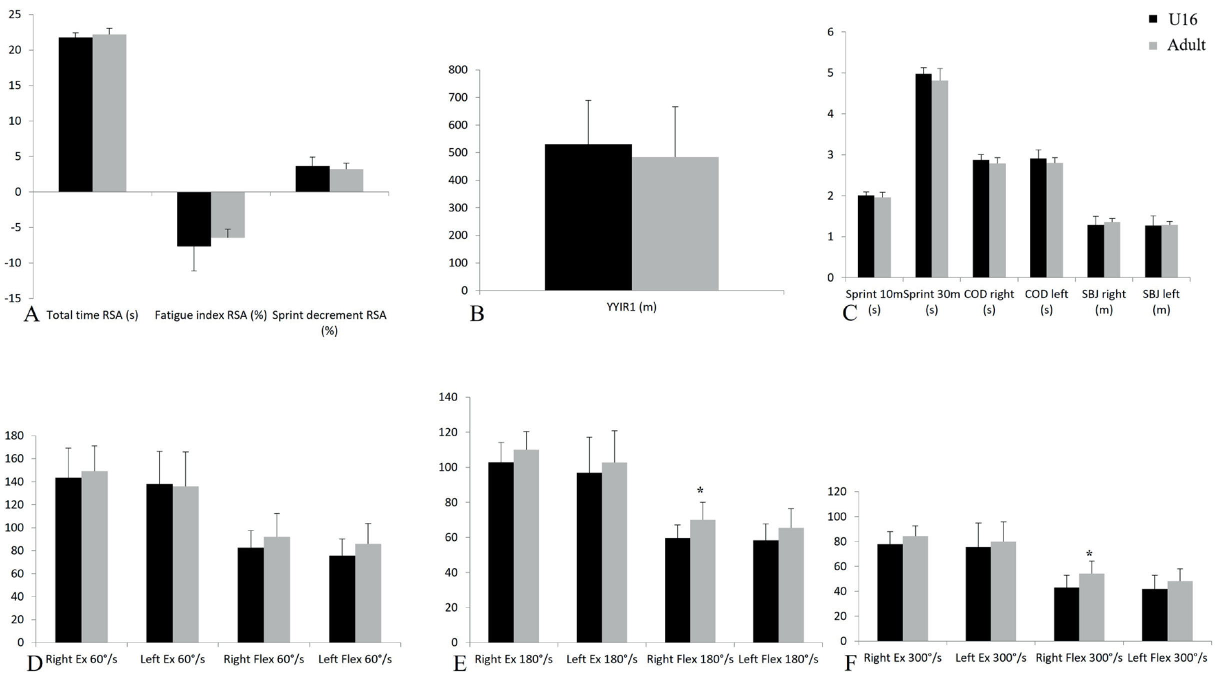
Correlations in the group of adult female soccer players

The results of the statistical analysis showed a large positive correlation ($r = 0.643$, $p = 0.024$) between RSATT and S10-m, a large positive correlation $r = 0.617$, $p = 0.032$) between RSATT and COD right, a very large positive correlation ($r = 0.749$, $p = 0.013$) between Sdec% and Ex def 60°/s, a large positive correlation ($r = 0.682$, $p = 0.030$) between Sdec% and L Ratio F/E 60°/s, a large negative correlation ($r = –0.699$, $p = 0.024$) between Sdec% and Flex def 300°/s (Table 2).

Discussion

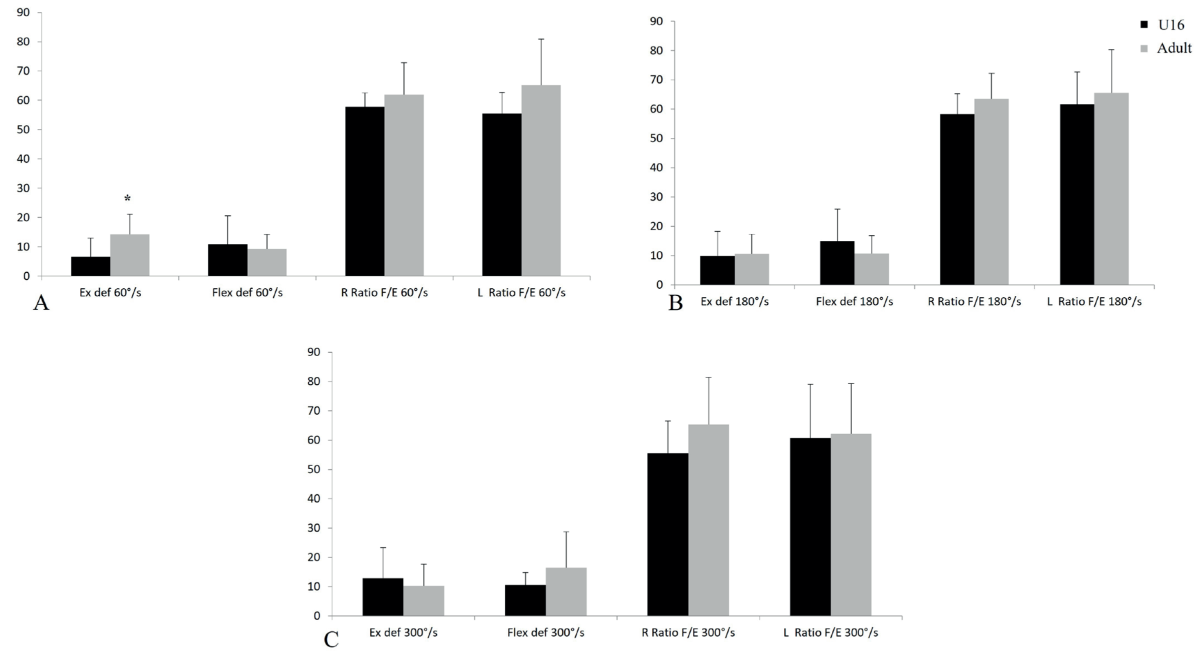
Comparison between the two age groups

As mentioned before, the aim of this study was to examine the relationship between the ability to perform repeated sprints (6 × 20 m in a 15-s cycle) in female soccer players from two different age groups, with aerobic capacity (YYIR1), jumping ability (single-leg jump test), isokinetic strength (60°/s, 180°/s, 300°/s),



Note: RSA – repeated sprint ability; YYIR1 – Yo-Yo intermittent recovery test level 1; COD – change of direction; SBJ – single-leg broad jump; Flex – flexor muscles; Ex – extensor muscles
* denotes significant difference at $p < 0.05$

Figure 2. Performance of the two groups in: A. the RSA test (total time, fatigue index, sprint decrement); B. the Yo-Yo intermittent recovery level 1 test; C. the sprint test (10 m and 30 m), COD test, jump test; D. isokinetic strength 60°/s; E. isokinetic strength 180°/s; F. isokinetic strength 300°/s



Note: Flex – flexor muscles; Ex – extensor muscles; def – deficit; R – right; L – left; F/E – ratio flexors/extensors
* denotes significant differences between the two groups

Figure 3. The deficit between the two legs in the strength of knee flexors and extensors and the ratio of knee flexor to extensor strength of both legs at: A. 60°/s; B. 180°/s; C. 300°/s

Table 1. Correlations of variables from the RSA test (RSATT, FI, Sdec%) with variables from physical fitness tests in the field and laboratory for the U-16 female soccer players

	RSATT	FI	Sdec%
YYIR1	r = –0.527, p = 0.078	r = 0.443, p = 0.150	r = –0.271, p = 0.394
Sprint 10 m	r = 0.608, p = 0.036*	r = –0.227, p = 0.477	r = 0.167, p = 0.604
Sprint 30 m	r = 0.883, p<0.001**	r = 0.050, p = 0.876	r = –0.091, p = 0.778
COD R	r = 0.285, p = 0.370	r = –0.202, p = 0.529	r = 0.165, p = 0.609
COD L	r = 0.296, p = 0.351	r = 0.088, p = 0.786	r = –0.033, p = 0.920
COD def	r = 0.164, p = 0.610	r = –0.180, p = 0.576	r = 0.155, p = 0.631
SBJ R	r = –0.631, p = 0.028*	r = 0.097, p = 0.764	r = 0.083, p = 0.797
SBJ L	r = –0.694, p = 0.012*	r = 0.301, p = 0.342	r = –0.017, p = 0.957
SBJ def	r = 0.326, p = 0.301	r = –0.458, p = 0.134	r = 0.297, p = 0.349
R Ex 60°/s	r = 0.109, p = 0.735	r = –0.109, p = 0.737	r = –0.001, p = 0.999
L Ex 60°/s	r = 0.057, p = 0.860	r = –0.194, p = 0.546	r = 0.024, p = 0.942
Ex def 60°/s	r = –0.130, p = 0.687	r = –0.075, p = 0.816	r = 0.237, p = 0.458
R Flex 60°/s	r = –0.014, p = 0.966	r = –0.257, p = 0.420	r = 0.144, p = 0.656
L Flex 60°/s	r = –0.092, p = 0.775	r = 0.217, p = 0.499	r = –0.209, p = 0.514
Flex def 60°/s	r = 0.002, p = 0.996	r = –0.744, p = 0.006*	r = 0.627, p = 0.029*
R Ratio F/E 60°/s	r = –0.251, p = 0.431	r = –0.336, p = 0.285	r = 0.310. p = 0.327
L Ratio F/E 60°/s	r = –0.235, p = 0.463	r = 0.607, p = 0.036*	r = –0.330, p = 0.294
R Ex 180°/s	r = –0.163, p = 0.613	r = –0.008, p = 0.981	r = –0.080, p = 0.805
L Ex 180°/s	r = –0.047, p = 0.884	r = –0.053, p = 0.870	r = –0.099, p = 0.760
Ex def 180°/s	r = –0.175, p = 0.586	r = –0.252, p = 0.429	r = 0.417, p = 0.177
R Flex 180°/s	r = –0.038, p = 0.907	r = –0.394, p = 0.205	r = 0.266, p = 0.403
L Flex 180°/s	r = –0.522, p = 0.082	r = 0.584, p = 0.046*	r = –0.528, p = 0.078
Flex def 180°/s	r = 0.170, p = 0.598	r = –0.528, p = 0.078	r = 0.273, p = 0.390
R Ratio F/E 180°/s	r = 0.090, p = 0.782	r = –0.442, p = 0.150	r = 0.387, p = 0.214
L Ratio F/E 180°/s	r = –0.374, p = 0.232	r = 0.495, p = 0.102	r = –0.278, p = 0.381
R Ex 300°/s	r = –0.274, p = 0.389	r = 0.102, p = 0.753	r = –0.128, p = 0.692
L Ex 300°/s	r = –0.072, p = 0.824	r = 0.007, p = 0.984	r = –0.170, p = 0.598
Ex def 300°/s	r = –0.255, p = 0.425	r = –0.466, p = 0.127	r = 0.514, p = 0.087
R Flex 300°/s	r = –0.458, p = 0.134	r = –0.089, p = 0.784	r = 0.077, p = 0.813
L Flex 300°/s	r = –0.441, p = 0.151	r = –0.043, p = 0.895	r = 0.105, p = 0.747
Flex def 300°/s	r = –0.154, p = 0.632	r = 0.092, p = 0.776	r = –0.186, p = 0.563
R Ratio F/E 300°/s	r = –0.353, p = 0.260	r = –0.174, p = 0.588	r = 0.190. p = 0.555
L Ratio F/E 300°/s	r = –0.465, p = 0.128	r = –0.004, p = 0.991	r = 0.177, p = 0.581

Note: RSA – repeated sprint ability; RSATT – RSA total time; FI – decrease in sprint performance from the first to the last sprint; Sdec% – sprint decrement (%); YYIR1 – Yo-Yo intermittent recovery test level 1; COD – change of direction; SBJ – single-leg broad jump; Flex – flexor muscles; Ex – extensor muscles; def – deficit; R – right; L – left; F/E – ratio flexors/extensors
* denotes significant difference at $p < 0.05$; ** denotes significant difference at $p < 0.001$

Table 2. Correlations of variables from the RSA test (RSATT, FI, Sdec%) with variables from physical fitness tests on the field and in the laboratory for adult female soccer players

	RSATT	FI	Sdec%
YYIR1	r = –0.484, p = 0.111	r = –0.336, p = 0.286	r = 0.226, p = 0.480
Sprint 10m	r = 0.643, p = 0.024*	r = 0.302, p = 0.339	r = –0.301, p = 0.341
Sprint 30m	r = 0.447, p = 0.145	r = 0.319, p = 0.312	r = –0.035, p = 0.913
COD R	r = 0.617, p = 0.032*	r = 0.238, p = 0.456	r = –0.270, p = 0.396
COD L	r = 0.140, p = 0.664	r = 0.136, p = 0.673	r = –0.244, p = 0.444
COD def	r = –0.239, p = 0.454	r = –0.188, r = 0.558	r = 0.102, p = 0.752
SBJ R	r = –0.439, p = 0.153	r = –0.210, p = 0.513	r = 0.084, p = 0.794
SBJ L	r = –0.400, p = 0.198	r = –0.041, p = 0.899	r = 0.067, p = 0.837
SBJ def	r = 0.443, p = 0.149	r = –0.031, p = 0.924	r = 0.049, p = 0.881
R Ex 60°/s	r = –0.492, p = 0.148	r = –0.056, p = 0.878	r = 0.205, p = 0.571
L Ex 60°/s	r = –0.398, p = 0.255	r = 0.121, p = 0.740	r = –0.183, p = 0.614
Ex def 60°/s	r = 0.126, p = 0.729	r = –0.450, p = 0.192	r = 0.749, p = 0.013*
R Flex 60°/s	r = –0.565, p = 0.089	r = –0.550, p = 0.099	r = 0.532, p = 0.114
L Flex 60°/s	r = –0.398, p = 0.254	r = –0.481, p = 0.160	r = 0.509, p = 0.133
Flex def 60°/s	r = 0.192, p = 0.596	r = 0.338, p = 0.339	r = 0.051, p = 0.888
R Ratio F/E 60°/s	r = –0.307, p = 0.387	r = –0.607, p = 0.063	r = 0.472, p = 0.169
L Ratio F/E 60°/s	r = 0.008, p = 0.984	r = –0.582, p = 0.078	r = 0.682, p = 0.030*
R Ex 180°/s	r = –0.426, p = 0.219	r = –0.184, p = 0.611	r = 0.179, p = 0.620
L Ex 180°/s	r = –0.254, p = 0.479	r = –0.024, p = 0.947	r = –0.118, p = 0.744
Ex def 180°/s	r = –0.069, p = 0.849	r = –0.266, p = 0.458	r = 0.552, p = 0.098
R Flex 180°/s	r = –0.274, p = 0.443	r = –0.578, p = 0.080	r = 0.422, p = 0.224
L Flex 180°/s	r = –0.038, p = 0.918	r = –0.386, p = 0.270	r = 0.511, p = 0.131
Flex def 180°/s	r = 0.468, p = 0.172	r = 0.533, p = 0.112	r = –0.590, p = 0.072
R Ratio F/E 180°/s	r = –0.038, p = 0.918	r = –0.525, p = 0.119	r = 0.379, p = 0.280
L Ratio F/E 180°/s	r = 0.133, p = 0.715	r = –0,311, p = 0.381	r = 0.526, p = 0.119
R Ex 300°/s	r = –0.430, p = 0.215	r = –0.106, p = 0.770	r = 0.076, p = 0.835
L Ex 300°/s	r = –0.151, p = 0.677	r = 0.037, p = 0.920	r = –0.096, p = 0.792
Ex def 300°/s	r = –0.041, p = 0.910	r = –0.286, p = 0.422	r = 0.407, p = 0.243
R Flex 300°/s	r = 0.006, p = 0.986	r = –0.208, p = 0.564	r = –0.016, p = 0.966
L Flex 300°/s	r = 0.187, p = 0.605	r = –0.368, p = 0.295	r = 0.499, p = 0.142
Flex def 300°/s	r = –0.007, p = 0.985	r = 0.550, p = 0.100	r = –0.699, p = 0.024*
R Ratio F/E 300°/s	r = 0.134, p = 0.712	r = –0.125, p = 0.732	r = –0.024, p = 0.948
L Ratio F/E 300°/s	r = 0.118, p = 0.745	r = –0.426, p = 0.220	r = 0.568, p = 0.087

Note: RSA – repeated sprint ability; RSATT – RSA total time; FI – decrease in sprint performance from the first to the last sprint; Sdec% – sprint decrement (%); YYIR1 – Yo-Yo intermittent recovery test level 1; COD – change of direction; SBJ – single-leg broad jump; Flex – flexor muscles; Ex – extensor muscles; def – deficit; R – right; L – left; F/E – ratio flexors/extensors
* denotes a significant difference at $p < 0.05$

speed performance (S10-m and S30-m), and COD ability (505 COD test). The second objective of the study was to compare the performances of the two different groups in the tests. The initial assumption that the two groups would differ in all the measurements was not confirmed. As mentioned above, the two groups differed only in the isokinetic strength of the right leg at 180°/s and 300°/s and at the deficit between the two legs in the strength of the knee extensor muscles at 60°/s. More specifically, the older players exhibited a greater deficit between the two legs in the strength of the knee extensor muscles at 60°/s, as well as higher values of strength in the knee flexor muscles of the right leg at 180°/s and 300°/s.

Regarding the strength of the knee extensor and flexor muscles of both legs, Eustace et al. [15] also found differences in isokinetic muscle strength between different age groups. Specifically, older female soccer athletes showed higher values of strength during eccentric contractions of the knee flexor muscles of both the dominant and non-dominant leg and during concentric contractions of the knee extensor muscles of both the dominant and non-dominant leg at all examined velocities (60°/s, 180°/s, and 270°/s). However, in our study the athletes were evaluated only for concentric contractions, unlike the previous research mentioned. In the study by Manson et al. [36], differences in isokinetic strength were also found between three different age groups. More specifically, U-17 female soccer players exhibited lower strength values during concentric and eccentric knee flexion at 60°/s compared to U-20 and adult female soccer players. Additionally, the U-17 female soccer players had lower strength values during eccentric knee extension at 60°/s compared to the U-20 female players. However, the study by Manson et al. [36] did not examine the other two angular velocities (180°/s and 300°/s) used in our current research. On the other hand, Hannon et al. [24] did not find differences in muscle strength between the two age groups they studied at 60°/s and 180°/s. However, these researchers studied different age groups (10-14 years old and 15-18 years old) compared to our current work and used a different protocol to assess the isokinetic muscle strength of the knee extensors and flexors. In another study by Holmes and Alderink [25], no difference was found in the isokinetic strength of the quadriceps and hamstring muscles at 60°/s and 180°/s between two different age groups (15-16 years old and 17-18 years old). However, also in that case the researchers used a different isokinetic dynamometer protocol and the sport of the participants is unknown. Additionally, the age groups compared in the study by Holmes and Alderink [25] had fewer years between them compared to the age groups in our study. For all the remaining variables (RSATT, FI, Sdec%, S10-m and S30-m, YYIR1, COD, and SBJ), there were no differences between the two age groups.

Due to the lack of research on females, references are made to studies conducted on males. Previous research analyzing this topic [20] found differences in the fastest sprint and total time of the RSA test between male soccer players from two different age groups (U-17, U-19), while they found no differences between the two groups in the percentage decrease during the six sprints performed in the test. Another study [49] reported no differences in 5 and 10-m sprints among male soccer players aged 14-18, but differences were found in the 20-m sprint, YYIR1, and COD with the dominant and non-dominant leg. Also, another study [31] recorded no differences between two different age groups (19.29 ± 1.1 and 21.20 ± 1.32) of male soccer players in 5, 10, and 30-m sprints, SBJ, COD, RSATT, percentage decrement in the RSA test, and YYIR2. In a study by Fiorilli et al. [17], differences were found in COD in U-12, U-14, U-16, and U-18. The above studies conducted on male soccer players indicate that it is particularly difficult to compare and explain the results, as they differ in the tests used, the age of the participants and their level and equipment. However, we can observe that the wider the range of age groups, the more likely differences are to be observed. In the current study, differences were observed only in some strength variables between the two age groups and in no other physical ability tests.

It becomes evident that there is a significant lack of research in the literature concerning the comparison of female soccer players of different ages in fitness tests. It has been observed that in male soccer, differences emerge with age in various fitness tests, and it would be worthwhile to examine whether the same occurs in women's soccer. The results of this study did not reveal many differences between the two age groups studied. This is interesting, because in the U-16 group athletes are still developing physically and may lag in their performance in fitness tests compared to adult athletes [29, 45]. Additionally, female athletes differ in training experience by approximately three years. The fact that the female athletes did not differ significantly from one another in many of the fitness tests used may be influenced by training frequency and methods. It might also suggest that the difference in the level, at which they compete is due to technical and tactical characteristics rather than fitness. It would be interesting to investigate in the future whether the absence of differences between the two age groups in almost all the variables examined in this study translates into a lack of differences in variables related to their running profile during the match (e.g., total distance covered, meters in different speed zones, the number of sprints, etc.).

Correlation of the repeated sprints performance with the performance in fitness tests of soccer female athletes on the field and in the laboratory

The hypothesis that strong correlations will be observed between the YYIR1 test, the parameters of the RSA test and the speed tests was partially confirmed. More specifically for U-16 group, large positive correlations were observed between RSATT and S10-m and S30-m, respectively, along with a large negative correlation between RSATT and SBJ left and right, a very large negative correlation, a large positive correlation, and a large positive correlation between FI and the deficit between the two legs in the strength of the knee flexor muscles at 60°/s, the ratio of the strength of the knee flexor and extensor muscles of the left leg at 60°/s, and the strength of the knee flexor muscles of the left leg at 180°/s, respectively. Lastly, there was a large positive correlation between Sdec% and the deficit between the two legs in the strength of the knee flexor muscles at 60°/s. The results for the group of female athletes over the age of 18 showed a large positive correlation between RSATT and S10-m and COD right, respectively, a very large positive correlation, a large positive correlation, and a large negative correlation between the Sdec% and the deficit between the two legs in the strength of the knee extensor muscles at 60°/s, the ratio of the strength of the knee flexor and extensor muscles of the left leg at 60°/s, and the deficit between the two legs in the strength of the knee flexor muscles at 300°/s, respectively.

Initially, it should be noted that there is no research in the literature that examines the existence of correlations between RSA test and various laboratory and field fitness tests for U-16 female soccer players.

In the present study, no correlation between the variables of the RSA test and the YYIR1 was found for both age groups. Similarly to our findings, Lockie et al. [32] also found no correlation between the variables of the RSA test and the YYIR1 in women soccer players around the age of 20. However, other studies have found correlations between RSA test variables and the YYIR1 [12, 22] or other tests related to aerobic capacity [2, 46]. Still, a comparison with our research can only be made with those that used the same RSA test and the YYIR1 [12, 32]. Therefore, based on the results of the present study and those of Lockie et al. [32] no correlation is evident between total time, fatigue index, Sdec%, and the percentage decrement with YYIR1 in U-16 and adult female soccer players. The findings of the present study are consistent with those of Lockie et al., possibly because the same tests were used to assess RSA and because the sample shared some common characteristics. Certainly, as mentioned above, Doyle et al. [12] found a correlation between RSATT and the time of the first sprint in the RSA test with the YYIR1 test. It is worth noting that the athletes who participated in the above-mentioned study by Doyle et al. [12] were elite-level, unlike the athletes in our study. It might have been expected that there would be some correlation between RSA test variables and a test assessing aerobic capacity, such as YYIR1, since high aerobic capacity accelerates recovery after high-intensity efforts like sprints [44]. Additionally, since an RSA test includes intermittent maximal efforts, it would have been possible for a fatigue variable from it (e.g., a fatigue index) to be correlated with another intermittent running test like YYIR1. This could be because fatigue affects performance in the RSA test [18, 31] and YYIR1 [30]. However, as mentioned in the present research, for both age groups no correlation was evident between the RSA test variables and the YYIR1. Furthermore, Rampinini et al. [43] argued that although aerobic capacity contributes to it, other physiological parameters may be more important for improving the ability to perform repeated sprints in trained soccer players.

Furthermore, in the present study there appeared to be a correlation between RSATT and S10-m for both groups. However, only for the group of younger female athletes there seemed to be a correlation between RSATT and S30-m. In these two variables (S10-m and S30-m), Lockie et al. [32] reported data partially consistent with the findings of the present study, as they found a correlation between RSATT and S10-m and S30-m in the adult female athletes they studied. Similarly, Doyle et al. [12] found a very large positive correlation between RSATT and S10-m and S20-m in adult female athletes. Also, they found an almost perfect correlation between RSATT and S30-m. Moreover, Shalfawi et al. [46] also reported a correlation between the total, mean, and fastest time in the RSA test (different from ours) and S40-m in adult female athletes. Gonçalves et al. [22], using a different RSA test than ours and studying female soccer athletes aged around 23 years, found no correlation between different variables (minimum and maximum peak power, fatigue index – a different equation from the one used in the present study) from the RSA test and S10-m and S30-m. The result of the correlation between RSATT and sprint over 10 and 30 m was somewhat expected, as both tests involve achieving maximum speed in a straight line, supporting the results of studies conducted in male soccer [8, 27, 33]. From the results of the present study and existing literature it appears that maximum linear speed is the variable that most affects RSA.

Additionally, the results of the study showed a correlation between RSATT and COD in the group of adult female soccer athletes. In female soccer players of similar age to those in our study, Lockie et al. [32], using the same RSA test and the same agility test as in those in our study, also found a correlation between RSATT and percentage decrement and COD left. In other studies that applied different RSA tests and agility tests, significant correlations were not found between variables from the RSA test and those from the agility test [22, 46]. Although the 505 is a COD speed test, it still features two 5-m linear sprints performed around the direction change [40]. As a result, an individual's linear speed capabilities can still have a positive influence on 505 performance [40]. As mentioned earlier, in the group of adults RSATT correlated with S10-m, which measures athletes' acceleration [31, 33], and is necessary for performing the 505 COD test.

Furthermore, a correlation was found between RSATT and SBJ right and left in the group of U-16 female athletes. So far, there has been no study to examine potential correlations between variables from the RSA test and SBJ in female U-16 soccer players, or in adult female soccer athletes. Lockie et al. [32] found no correlation between RSATT and percentage decrement with a bilateral jump, while other researchers used vertical jumps and not horizontal ones in their studies [22, 46]. Lower limb strength has been correlated with sprint time in female athletes [41]. To run faster, an athlete needs to have the ability to utilize their overall strength and power during the sprint, which requires good neuromuscular control [51].

This is the first study to investigate correlations between variables from the RSA test and strength variables from the isokinetic dynamometer. Previous researchers have attempted to correlate variables from the RSA test with isometric hip adductor and abductor strength [22] and with maximal squat strength [32]. More research is needed to explain the correlation between variables from the isokinetic dynamometer and those from the RSA tests. Nevertheless, it appears that imbalances between the lower limbs and the ratio of knee flexor to extensor muscle strength in the lower limbs affect fatigue variables from the RSA test, as several correlations emerged between fatigue variables from the RSA test and variables related to lower limb imbalances and the ratio of knee flexor and extensor muscle strength, as assessed by the isokinetic dynamometer.

There are some limitations in the current research that need to be mentioned. The sample size of the study was limited. Future research should study groups of different ages and levels. Additionally, in this specific research a particular test designed for female soccer athletes was used [18]. Another RSA test with more sprint meters or more repetitions could alter the correlations of total time, fatigue index, and sprint decrement from the RSA test with the fitness tests used. Lastly, differences between the two age groups and the correlations mentioned could be influenced not only by a different RSA test, but also by the timing of measurements (preparation period, transitional period).

Conclusions

In conclusion, it appears that Greek female soccer players under the age of 16 do not significantly differ from adults in most of the fitness tests conducted, both in the field and laboratory settings. These tests include the RSA test, YYIR1, S10-m, S30-m, 505 COD test, SBJ, and isokinetic evaluation of strength at 60°/s, 180°/s, and 300°/s. However, notable differences were found in the deficit between the two legs in knee extensor strength at 60°/s and the knee flexor strength of the right leg at 180°/s and 300°/s. Practically, this means that U-16 female athletes are physically capable of participating and competing with adult female soccer players. S10-m, S30-m, and SBJ appear to be the variables most correlated with the total time in the RSA test for U-16 female soccer players. S10-m and COD, which require rapid acceleration, seem to be the variables most correlated with the total time in the RSA test for adult female athletes. In practice, this suggests that conditioning coaches can improve performance in RSA by enhancing speed at 10 and 30 m, SBJ, and COD ability in these two age groups.

Conflict of Interest

The authors declare no conflict of interest.

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