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# Correlation Between $VO_{2max}$ Estimates of the 30-15 Intermittent Fitness Test and the 20-m Shuttle Run Test in Professional Female Volleyball Players

**Onur ÇOBAN[1], Berkant Erman[2], Mehmet Zeki Özkol[3]**
[1]Independent Researcher, Muğla, Türkiye
https://orcid.org/0000-0002-3663-9039
[2]Independent Researcher, İzmir,Türkiye
https://orcid.org/0000-0002-0276-1298
[3]Coaching Education Department, Faculty of Sport Sciences, Ege University, Bornova, Izmir, Turkey
https://orcid.org/0000-0003-2418-7036
**Email:** onurcoban12@gmail.com, ermanberkant@gmail.com, zeki.ozkol@gmail.com

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## Abstract

Aerobic capacity is a crucial determinant of performance in volleyball, a sport characterized by intermittent high-intensity efforts. Field-based tests such as the 20-meter Shuttle Run Test (20 mSRT) and the 30-15 Intermittent Fitness Test (30-15 IFT) are commonly used to estimate maximal oxygen uptake ($VO_{2max}$) in athletes. However, the degree of consistency between these tests in elite female volleyball players remains unclear. This study aimed to compare $VO_{2max}$ estimates obtained from the 20 mSRT and 30-15 IFT in professional female volleyball players and assess the level of association and consistency between the two tests. Eight professional female volleyball players (age: 25.5 ± 3.74 years; height: 182.12 ± 6.57 cm; body mass: 73.87 ± 7.64 kg; BMI: 22.23 ± 1.35 kg/m²) completed both the 20 mSRT and 30-15 IFT. A paired-sample t-test was used to compare $VO_{2max}$ values between tests, and intraclass correlation coefficient (ICC 3,1) was calculated to assess the consistency between $VO_{2max}$ estimates. Pearson correlation analysis was also performed between the test results. $VO_{2max}$ values estimated from the 30-15 IFT (48.10 ± 5.03 $ml \cdot kg^{-1} \cdot min^{-1}$) were significantly higher than those from the 20 mSRT (35.49 ± 3.19 $ml \cdot kg^{-1} \cdot min^{-1}$) ($p < 0.001$, large effect size). A strong positive correlation was found between the two tests ($r = 0.833$, $p = 0.010$). However, the ICC (3,1) value of 0.754 (95% CI: 0.176–0.945) indicated a moderate level of consistency in ranking $VO_{2max}$ estimates derived from the two tests rather than equivalence of absolute values.

**Keywords**: Aerobic Capacity; 30-15 Intermittent Fitness Test; 20-m Shuttle Run Test; $VO_{2max}$; Body Mass Index

**Introduction**

Optimal athletic performance relies on various physical, mental, technical, and tactical components (Taware et al., 2013). Especially in high-intensity intermittent sports, accurately assessing these physiological characteristics in training and competition strategies plays a critical role in optimizing performance. In such sports, athletes must rapidly transition between short periods of high-intensity activity and recovery periods, making the interplay between anaerobic and aerobic metabolism a key determinant of performance. Athletes rely on anaerobic and aerobic systems to cope with the metabolic requirements of high-intensity sports. Aerobic capacity, usually expressed as maximal oxygen consumption ($VO_{2max}$), plays an important role in many athletic performances (Ranković et al., 2010). $VO_{2max}$ refers to the maximal capacity of the body to uptake and utilize oxygen during physical exertion, reaching a plateau despite increasing workload. In conclusion, $VO_{2max}$ is not only a physiological marker of endurance but also a valuable tool for athletes in various sport disciplines to follow their training adaptations and optimise their conditioning programmes. Furthermore, training at or close to $VO_{2max}$ is beneficial for improving aerobic capacity and ultimately athletic performance (Buchheit, Leprêtre, et al., 2009). $VO_{2max}$ is considered an important determinant for success, especially in team sports (Grgic et al., 2021). Therefore, a reliable assessment of $VO_{2max}$ is an indispensable requirement for monitoring athletes' training processes and optimising individual performance. Managing training load and understanding its physiological impact is crucial to optimise athletic performance (Valladares-Rodríguez et al., 2017).

Volleyball demands frequent transitions between rallies and recovery, making it an intermittent sport. Rallies are moments of competition where players showcase their sport-specific skills. The ratio of rallies to rest periods is approximately 1:3, giving players time to take a break from anaerobic performance (Junior, 2020). The rules and structure of the game create cycles of intense activity followed by recovery opportunities (VanHeest, 2003). Aerobic capacity plays a crucial role in supporting recovery between rallies and generating explosive power. It enables athletes to maintain high-intensity performance during competition (Kaynak et al., 2017).

Field tests have advantages in team sports due to their practicality and ease of implementation. Furthermore, $VO_{2max}$ tests performed in the laboratory cannot fully mimic the movement patterns and intermittent nature of many team sports, limiting their validity in applied sport science settings. It's possible to determine $VO_{2max}$ based on the total duration running on the treadmill, although this method also requires maximal effort (Foster et al., 1984). Furthermore, factors such as age and body mass index (BMI) may also influence $VO_{2max}$ values in these tests, affecting their accuracy and applicability in different athlete populations. Previous studies have suggested that variations in body composition may impact $VO_{2max}$ outcomes (McArdle et al., 2010). Therefore, investigating the correlations between BMI, and $VO_{2max}$ prediction results of both 20-m shuttle run test (20 mSRT), and 30-15 Intermittent Fitness Test (30-15 IFT) may provide valuable information for volleyball players about the applicability of these tests. Given the dynamic nature of team sports, selecting a test that accurately reflects the sport-specific needs is crucial for obtaining meaningful performance information. Choosing a test suitable for the physiological demands of volleyball is crucial for accurate fitness assessment and individualized conditioning programmes. The 20 mSRT and 30-15 IFT are two field tests commonly used to estimate $VO_{2max}$, especially in team sports (Nassis et al., 2010). The 20 mSRT is a widely validated predictor of $VO_{2max}$, showing strong correlations with treadmill-measured ($r = 0.90$) and retroextrapolated $VO_{2max}$ ($r = 0.87$) (L. Leger & Gadoury, 1989). Recent systematic reviews confirm the strong criterion-related validity of the 20 m shuttle run (Castro-Pinero et al., 2021). The 30–15 IFT has also been confirmed as a reliable assessment tool in elite female athletes (Križaj, 2025). The 30-15 IFT has shown strong reliability (ICC = 0.80–0.99) and efficacy in various sports (Bruce & Moule, 2017; Kelly et al., 2018; Thomas et al., 2016). However, their validity and applicability vary based on sport-specific demands and athlete characteristics. The 30-15 IFT has shown a strong correlation between the final running velocity (VIFT) and laboratory-measured $VO_{2max}$ (Buchheit et al., 2011). Unlike the 20 mSRT, the 30-15 IFT includes short recovery intervals, making it more similar to intermittent sports where players experience frequent transitions between high-intensity efforts and rest phases. Determining the most appropriate testing protocol is essential to obtain reliable information about athletes' physical capacity and training effectiveness (Ranković et al., 2010). However, there is limited research directly comparing these field tests in volleyball, a sport requiring both aerobic and anaerobic capacities for sustainable performance. Performance evaluations should utilize tests specifically designed for the targeted sport (Hernández-Davó, 2020).

The primary objective of this study was to investigate the relationship between $VO_{2max}$ values derived from the 30-15 IFT and the 20 mSRT in professional female volleyball players. Furthermore, this study investigates the relationship between BMI and the results of both field tests. By analysing these relationships, this study aims to contribute to a better understanding of how these field tests compare in predicting aerobic capacity in professional athletes. The findings may provide useful information for coaches and sports scientists in evaluation of aerobic fitness assessment methods for volleyball players.

## Material and Method

### Ethics Committee Permission

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ege University Medical Research Ethics Committee (protocol code 22-4,LT17 and date of approval 21.04.2022).

### Participants

Eight female volleyball players (age: 25.5 ± 3.74 years; height: 182.12 ± 6.57 cm; body mass: 73.87 ± 7.64 kg; BMI: 22.23 ± 1.35 kg/m²) participated. G*Power 3.1 software was used to perform t-test analyses and determine a sample size of eight with a power of (1-β) = 0.65, effect size (dz) = 0.8, and type-1 error (α) = 0.05. All participants provided written informed consent prior to taking part in the study. Participants were eligible for inclusion if they met the following criteria: (i) being a professional volleyball player competing at the national or international level, (ii) having at least five years of volleyball experience, and (iii) having no musculoskeletal injury in the last six months. Exclusion criteria included (i) any history of cardiovascular or respiratory diseases, (ii) previous lower extremity injuries affecting performance, and (iii) inability to complete both testing protocols. All procedures in this study followed the ethical guidelines outlined in the Declaration of Helsinki and were reviewed and approved by the Medical Research Ethics Committee of Ege University (22-4.1T/7).

### Procedures

Participants' height was assessed to the closest 0.1 cm with a calibrated vertical stadiometer (Holtain Ltd, UK) with the participant in anatomical posture. Body weight was measured to the nearest 0.1 kg on a weighing scale (Seca, Germany) with the participants in anatomical posture, wearing sportswear and without shoes. BMI was derived by dividing the participants' body mass (kg) by their height squared ($m^2$) (Nikolaidis, 2013).

Data collection occurred during the participants' preparation period. Both tests were performed at 10:30 am in an indoor sports hall, with a 72-hour break between test sessions. All tests were performed indoors at ambient temperatures ranging from 20 to 22°C and relative humidity levels between 50% and 60%. All participants were requested to avoid caffeine, strenuous exercise, and to follow standard pre-test dietary and sleep guidelines. Before each test, participants performed a structured 15 minutes preparation routine including 3 to 5 minutes of easy-paced running, drills targeting coordination and quickness, side-to-side movements, dynamic flexibility exercises, and five sets of progressively intense sprints incorporating directional changes (Dardouri et al., 2013). Standardised verbal encouragement and instructions were used during the test.

Prior to data collection, participants were subjected to practice sessions five days before the actual measurements to minimise possible learning effects. On the first day, participants' anthropometric characteristics such as height, weight, and BMI were measured. In addition, their performance in the 20 mSRT was assessed and estimated $VO_{2max}$ was calculated by a formula. On the second day, 30-15 IFT was completed and $VO_{2max}$ was estimated by a formula using the VIFT. To minimize order effects, the sequence of performing the 20 mSRT and 30-15 IFT was randomized for each participant.

**20-m Shuttle Run Test**

The 20 mSRT consisted of continuous shuttle runs between two cones placed 20 meters apart, with pace guided by a timed audio sequence. The initial velocity was set at 8 km/h and progressively rose in 0.5 km/h increments at one minute intervals. Participants pushed themselves to complete the maximum achievable distance. The test concluded once a participant missed the 3-meter target zone beyond the 20-meter lines three times consecutively, as indicated by the beep (Buchheit, 2008). The final level reached by each participant was documented and applied in a validated equation to predict $VO_{2max}$.

Formula for estimating $VO_{2max}$ from 20 mSRT;

$$VO_{2max} = 31.025 + [3.238 * Speed] – [3.248 * Age] + [0.1536 * Speed * Age]$$

In this formula, speed was calculated as [8 + (0.5 * Stage Number)], and age was used in years (L. A. Leger et al., 1988).

**30-15 Intermittent Fitness Test**

During the 30-15 IFT, participants perform intermittent 30 seconds high-intensity runs interspersed with brief 15 seconds recovery intervals. The initial running speed was set at 8 km/h, progressively rising in 0.5 km/h increments at 45 seconds intervals. Participants shuttle between two markers set 28 meters apart, adjusting their pace to match the rhythm of an audio beep signal. Speed adjustments are made by entering 3-meter areas at both ends and the central zone, timed with the brief beep signal. In the 15-second rest period, participants walk toward the closest marker, based on where they finished the previous bout, to initiate the following stage. The assessment concludes once a participant can no longer keep up with the required speed and fails to reach the 3-meter zones three times in succession. The velocity achieved in the final successfully completed stage is taken as the VIFT (Buchheit, 2008; Thomas et al., 2016).

Formula for estimating $VO_{2max}$ from 30-15 IFT;

$$VO_{2max} = 28.3 - (2.15 * G) - (0.741 * A) - (0.0357 * W) + (0.0586 * A * VIFT) + (1.03 * VIFT)$$

In this formula, G represents gender (female = 2; male = 1), A denotes age (years), and W stands for body mass (kg) (Buchheit, 2010).

## Data Analysis

To summarize the dataset, descriptive statistics such as including the mean, standard deviation, minimum and maximum values, skewness, and kurtosis were calculated for all variables. The assumption of normality was assessed using the Shapiro-Wilk test. As all variables met the criteria for normal distribution ($p > 0.05$), parametric tests were considered appropriate for further analysis. A paired-sample t-test was performed to compare $VO_{2max}$ estimates from the 20 mSRT and the 30-15 IFT. Cohen's d was calculated to determine the effect size and interpreted as follows, no effect (0.0-0.2), small (0.2-0.5), moderate (0.5-0.8), and large (>0.8). Pearson's correlation coefficient (r) was used to assess the relationships between $VO_{2max}$ values from 20 mSRT, 30-15 IFT and BMI. The Intraclass Correlation Coefficient (ICC) at 95% confidence interval was calculated to assess the consistency between $VO_{2max}$ estimates obtained from 20 mSRT and 30-15 IFT. The ICC (3,1) model was selected because it was suitable for evaluating the consistency of relative ranking between two field-based $VO_{2max}$ estimates. ICC values were interpreted as follows, poor (0.00-0.50), moderate (0.50-0.75), good (0.75-0.90), excellent (0.90-1.00) reliability. All statistical analyses were performed using SPSS (Version 25, IBM Corp., Armonk, NY, USA) , with statistical significance set at $p \leq 0.05$.

## Findings

Table 1 presents descriptive statistics, including mean ± standard deviation, minimum and maximum values, skewness, and kurtosis for 30-15 IFT, 20 mSRT, and BMI.

**Table 1.** Descriptive statistics.

| | **30-15 IFT** | **20 mSRT** | **BMI** |
|---|---|---|---|
| **Mean ± Std** | 48.10±5.03 | 35.49±3.19 | 22.23±1.45 |
| **Minimum** | 42.16 | 32.30 | 19.94 |
| **Maximum** | 56.538 | 40.80 | 24.10 |
| **Skewness** | 0.45 | 0.49 | -0.75 |
| **Kurtosis** | -0.74 | -1.02 | -0.34 |

Descriptive statistics revealed that the mean $VO_{2max}$ estimates were 48.10 ± 5.03 $ml \cdot kg^{-1} \cdot min^{-1}$ for 30-15 IFT and 35.49 ± 3.19 $ml \cdot kg^{-1} \cdot min^{-1}$ for 20 mSRT. The mean BMI of the participants was 22.23 ± 1.45 $kg/m^2$.

The Shapiro-Wilk test was applied to evaluate whether the data followed a normal distribution. The results are presented in Table 2. The results showed that 30-15 IFT ($p = 0.698$), 20 mSRT ($p = 0.193$), and BMI ($p = 0.175$) followed a normal distribution as their p-values were greater than 0.05. These findings confirm that the normality assumption was met and justify the use of parametric statistical analyses in subsequent comparisons and correlation assessments.

**Table 2.** Shapiro-Wilk test results.

| | **Shapiro-Wilk** | **p** |
|---|---|---|
| **30-15 IFT** | 0.949 | 0.698 |
| **20 mSRT** | 0.881 | 0.193 |
| **BMI** | 0.877 | 0.175 |

A paired samples t-test was conducted to examine the differences in $VO_{2max}$ estimates derived from the 30-15 IFT and the 20 mSRT. The results are presented in Table 3. Findings indicated a meaningful statistical disparity across the two testing protocols ($t = 12.062$, $p < 0.001$), $VO_{2max}$ values being higher at 30-15 IFT (48.10 ± 5.03 $ml \cdot kg^{-1} \cdot min^{-1}$) compared to 20 mSRT (35.49 ± 3.19 $ml \cdot kg^{-1} \cdot min^{-1}$). The mean difference between the tests was 12.613 $ml \cdot kg^{-1} \cdot min^{-1}$, indicating a very large effect size (ES = 4.26). The effect size indicates a substantial difference between the two $VO_{2max}$ estimates, suggesting that these tests may yield systematically different $VO_{2max}$ estimates when assessing aerobic capacity.

**Table 3.** Paired T-test results.

| Measurement | Mean ± Std | Mean Diff. | *t* | ES | *p* |
|---|---|---|---|---|---|
| **30-15 IFT *vs* 20 mSRT** | 48.10 ± 5.03 vs 35.49 ± 3.19 | 12.613 | 12.062 | 4.26 | < 0.001* |

*: p< 0.05

Table 4 presents the correlation between BMI, 20 mSRT and 30-15 IFT. Pearson correlation analysis identified a strong positive relationship between $VO_{2max}$ values estimated from the 30-15 IFT and the 20 mSRT ($r = 0.833$, $p = 0.010$), suggesting a strong association between the two tests. However, BMI showed a negative correlation with both the 30-15 IFT ($r = -0.506$, $p = 0.201$) and the 20 mSRT ($r = -0.313$, $p = 0.451$), but these correlations were not statistically significant. These findings suggest that although the two field tests were strongly correlated in estimating $VO_{2max}$, BMI did not significantly influence test results in this sample ($p > 0.05$). This may indicate that BMI alone is not a strong predictor of aerobic fitness in this sample. However, a larger sample size might be needed to confirm this finding.

**Table 4.** Correlations between BMI, 20 mSRT and 30-15 IFT.

| Variables | | 30-15 IFT | 20 mSRT |
|---|---|---|---|
| **20 mSRT** | **r** | 0.833 | - |
| | **p** | 0.010* | - |
| **BMI** | **r** | - 0.506 | - 0.313 |
| | **p** | 0.201 | 0.451 |

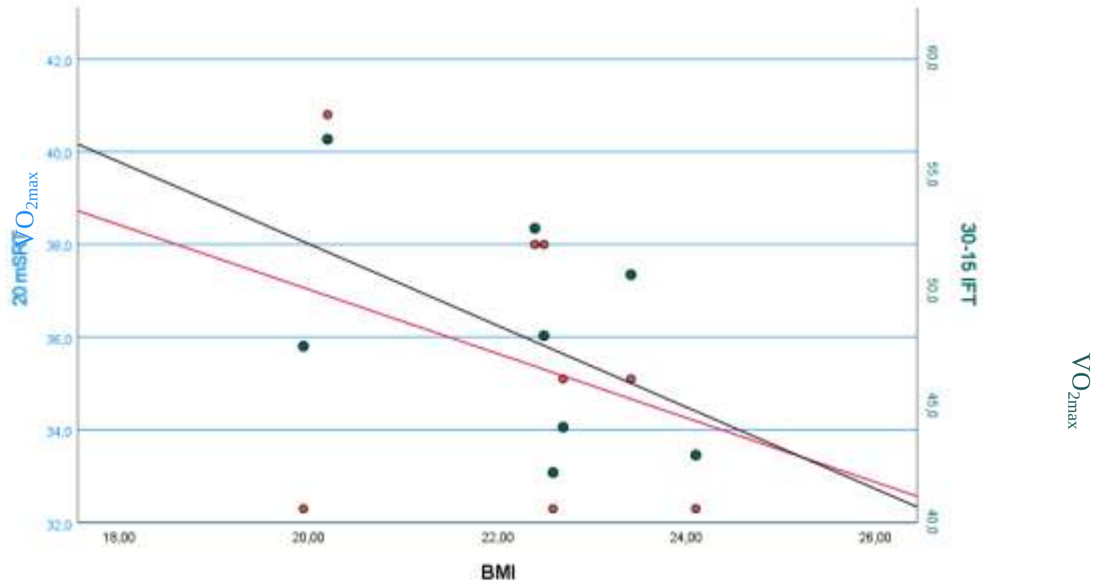
*: p< 0.05

To further assess the consistency between $VO_{2max}$ estimates from 30-15 IFT and 20 mSRT, ICC was calculated. ICC analysis revealed moderate consistency (ICC = 0.754, 95% CI: 0.176–0.945), indicating that the two tests, although related, show only moderate consistency in $VO_{2max}$ estimation. This moderate level of consistency suggests that these tests may capture different aspects of aerobic capacity, possibly due to the intermittent nature of the 30-15 IFT compared to the more continuous running protocol of the 20 mSRT.

**Table 5.** Intraclass correlation coefficient between 30-15 IFT and 20 mSRT.

| Type | ICC | Lower %95 CI | Upper %95 CI |
|---|---|---|---|
| **ICC 3,1** | 0.754 | 0.176 | 0.945 |

**Figure 1.** BMI and 20mSRT and 30-15 IFT Test Variables




## Discussion

High aerobic capacity is essential for sustain performance in multi-set volleyball games (Kaynak et al., 2017; Lidor & Ziv, 2010). Field-based tests such as 20 mSRT and 30-15 IFT are widely used to estimate $VO_{2max}$ in athletes. While the 20 mSRT has been extensively applied across various populations (Mayorga-Vega et al., 2015), the 30-15 IFT has proven its effectiveness in assessing aerobic fitness in intermittent sports (Buchheit et al., 2011; Scott et al., 2015; Valladares-Rodríguez et al., 2017). Furthermore, $VO_{2max}$ values obtained from the 30-15 IFT showed strong association with laboratory-based continuous treadmill tests (Jeličić et al., 2020). However, direct comparisons between the 30-15 IFT and 20 mSRT suggest differences in $VO_{2max}$ estimates.

In the present study, $VO_{2max}$ estimates from 30-15 IFT (48.10 ± 5.03 ml·kg$^{-1}$·min$^{-1}$) were significantly higher ($p < 0.001$) than those from 20 mSRT (35.49 ± 3.19 ml·kg$^{-1}$·min$^{-1}$). This significant difference is probably due to differences in test protocols. The intermittent nature of the 30-15 IFT, which includes recovery periods allowing partial phosphocreatine resynthesis through aerobic metabolic processes (Haydar et al., 2011), in contrast to the continuous, non-recovery design of the 20 mSRT, which may lead to earlier fatigue (Buchheit, Al Haddad, et al., 2009). Furthermore, differences in shuttle distances may also influence metabolic demands and patterns of exhaustion (Čović et al., 2016). The systematic difference in $VO_{2max}$ estimates suggests that these tests may not be interpreted as providing equivalent absolute $VO_{2max}$ values, as the 30-15 IFT tends to yield higher estimates than the 20 mSRT. However, despite these differences in absolute values, a strong correlation ($r = 0.833$, $p = 0.010$) indicates that the tests similarly rank athletes according to aerobic fitness. This suggests that although the estimated $VO_{2max}$ values are not directly interchangeable, both tests provide a similar ranking of athletes according to their aerobic capacity.

The 20 mSRT includes frequent 180 degree turns requiring rapid deceleration and acceleration, potentially leading to higher peak blood lactate concentrations and greater reliance on anaerobic metabolism. In contrast, the 30-15 IFT includes short recovery periods allowing for partial ATP-PC replenishment, which may lead to higher $VO_{2max}$ estimates compared to a continuous test format. The longer shuttle distance and built in recovery times of the 30-15 IFT may better mimic the intermittent demands of volleyball (Čović et al., 2016; Rey et al., 2016). These factors likely contribute to the observed differences in $VO_{2max}$ estimates while still maintaining a strong correlation between the tests.

Body composition is known to affect $VO_{2max}$ estimation. Although previous studies have shown a negative correlation between BMI and $VO_{2max}$ (Matsuzaka et al., 2004; Setty et al., 2013; Shah et al., 2016), our study found no statistically significant correlations between BMI and $VO_{2max}$ estimates for both tests (30-15 IFT: $r = -0.507$, $p = 0.200$; 20 mSRT: $r = -0.314$, $p = 0.449$). This suggests that BMI alone may not be a determining factor in $VO_{2max}$ estimation for this particular cohort. However, the non-significant results could also stem from the limited number of participants.

The ICC (3,1) between the two tests was 0.754 (95% CI: 0.176–0.945), indicating a moderate level of consistency in relative $VO_{2max}$ ranking between the two field tests. However, the wide confidence interval, especially with a lower bound close to zero, suggests considerable variability between participants, possibly due to individual differences in anaerobic capacity, running mechanics or adaptation to intermittent and continuous exercise protocols. This variability underlines the need for careful interpretation of these tests in different athletic contexts. Although the strong correlation indicates that both tests rank aerobic fitness similarly, the systematic difference in $VO_{2max}$ values further confirms that they should not be used interchangeably. Instead, these tests should be interpreted according to their specific predictive properties, the 30-15 IFT provides information on intermittent aerobic capacity whereas the 20 mSRT reflects continuous endurance performance (Buchheit, Al Haddad, et al., 2009).

Hormonal fluctuations across the menstrual cycle may introduce several confounding factors that complicate both study design and interpretation of outcomes. Importantly, elite female athletes frequently experience menstrual disturbances. These variations can influence multiple physiological domains, including cardiovascular and respiratory responses, as well as metabolic regulation, ultimately impacting aerobic performance capacities (Meignié et al., 2021). Therefore, the lack of menstrual cycle monitoring in the present study should be considered a limitation and warrants careful consideration in future research.

## Conclusion

This research has shown that although the 30-15 IFT and 20 mSRT show a strong correlation in ranking individuals according to their $VO_{2max}$, they consistently give different estimates. These differences are likely due to differences in testing protocols, recovery intervals, and metabolic demands. Therefore, these assessments should not be considered equivalent in terms of absolute $VO_{2max}$ estimation, but should be interpreted according to their distinct physiological and methodological characteristics. Based on these results, it can be argued that the 30-15 IFT is a more appropriate test to measure aerobic fitness in intermittent sports such as volleyball. Moreover, the prediction formula of the 30-15 IFT also includes gender and body mass, which may facilitate more specific $VO_{2max}$ estimates compared to the 20 mSRT. In this study, no significant correlation was found between BMI and $VO_{2max}$ estimates, suggesting that BMI alone may not be an important factor in assessment of aerobic capacity.

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