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Comparing the 30–15 intermittent fitness test and treadmill test on $\dot{V}O_2$ max in elite female footballers

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ABSTRACT

Purpose. The study compared the 30–15 intermittent fitness test (30–15 IFT) and the treadmill-based multistage incremental test to evaluate their effectiveness in assessing cardiorespiratory fitness in elite female football players.

Methods. Fifteen Slovenian National A Team female football players (age = 24.4 ± 5.7 years; height = 166.5 ± 6.2 cm; weight = 59.9 ± 6.0 kg) completed the 30–15 IFT and treadmill tests on separate occasions. Maximal running speed (MRS), maximal oxygen consumption ($\dot{V}O_2$ max), and maximum heart rate (HRmax) were measured, with Pearson's correlation coefficients used to assess their relationships.

Results. A moderate positive correlation was found between mean MRS treadmill speed (MRS_Treadmill) and $\dot{V}O_2$ max from the 30–15 IFT (r = 0.533, p = 0.041). The $\dot{V}O_2$ max from the 30–15 IFT and treadmill test showed a strong correlation (r = 0.756, p = 0.002), while the correlation between treadmill $\dot{V}O_2$ max and mean MRS 30–15 IFT speed (MRS_30–15 IFT) was nearly perfect (r = 0.977, p = 0.000). The intraclass correlation coefficient (ICC) for single $\dot{V}O_2$ max measurements was 0.689 [95% confidence interval (CI) = 0.271–0.888, p = 0.002], indicating moderate agreement, and 0.816 (95% CI: = 0.426 – 0.941, p = 0.002) for average measurements, indicating strong agreement.

Conclusions. These results are important for coaches of elite women's football. The reduced variability suggests that cardiorespiratory fitness measures are more consistent in elite athletes than in diverse sports populations. This study's unique contribution lies in its focus on elite national female football players, providing specific findings that enhance the utility of the 30–15 IFT in this specialised context.

Key words: elite female football, maximum oxygen uptake, laboratory/treadmill test, field run test, physical performance

Introduction

Women's football is rapidly evolving in many areas, with the latest report from the Fédération Internationale de Football Association [1] highlighting significant advancements, including the demand for higher coaching qualifications, the establishment of youth academies for girls, increased broadcasting revenue, and improved player salaries. These developments demonstrate the growing professionalism and global reach of the sport, especially at the elite level. In addition, modern elite women's football is becoming more physically demanding, with more intense running periods across various playing positions [2, 3].

Recent advances in performance measurement technologies, such as Global Positioning Systems (GPS) and optical tracking systems, have improved physical condition assessment in football. These technologies enable precise measurements of key performance metrics such as running distances, intensities, and acceleration profiles [4–7]. In addition, new technologies, such as optical tracking systems, enable even more specific and intensive tracking and analysis of performance [8].

According to Pons et al. [9], both GPS devices and optical tracking systems in football are an invaluable tool for assessing the performance of players during a match. For example, they provide real-time data on key performance metrics like total distance covered, high-intensity running, and acceleration profiles, allowing coaches to make tactical adjustments, such as substituting players who show signs of reduced running capacity. In addition, the comprehensive insights into performance that these systems provide facilitate the development of evidence-based training programs

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aimed at improving physical conditioning, optimizing tactical execution, and enhancing overall team and individual performance.

Coaches are increasingly relying on science-based data to understand the physical demands of football. The data forms the basis for the development of well-structured training sessions, such as cardiorespiratory fitness programs, which aim to improve players' ability to sustain repeated high-intensity actions throughout a match [10, 11]. Scientifically-based monitoring techniques, such as heart rate (HR) monitoring, GPS tracking, and lactate testing, provide valuable insights into players' physical performance [12], helping to identify critical performance factors. With this information, coaches can design training programs that address the key determinants of football performance [13].

Cardiorespiratory fitness is a fundamental component of physical performance in football, alongside strength, speed, and coordination [14]. It is thought to significantly impact peak performance, as it supports sustained high-intensity running during the game and prevents a decrease in performance intensity as the game progresses [15]. In both women's and men's football, players perform various high-intensity activities throughout the game, such as short sprints, kicks, jumps, and tackles, all of which require high levels of anaerobic fitness [12]. The gold standard metric for assessing a football player's aerobic capacity is maximal oxygen consumption ($\dot{V}O_2$ max) [16], a holistic indication of the body's ability to utilise oxygen during maximal exertion. $\dot{V}O_2$ max is directly related to football performance, as it can indicate a player's endurance, recovery ability, and ability to sustain high-intensity effort during a match [17]. Higher performance levels in women's football are associated with better $\dot{V}O_2$ max values. For example, the female Norwegian national team players demonstrated higher $\dot{V}O_2$ max values than the Norwegian first and second-division female players [18], a comparison reflected in their junior female national team players relative to players in other junior female categories. In this context, well-developed cardiorespiratory fitness helps football players efficiently use oxygen to perform repetitive high-intensity actions and accelerate the recovery process during a football match [19].

The 30–15 intermittent fitness test (30–15 IFT) is one of the most commonly used methods for assessing cardiorespiratory fitness in football and other team sports [20–24]. Quantifying improvements in fitness tests of this type is crucial for accurately monitoring player development in sport-specific contexts. In football, for example, the ability to sustain high-intensity sprints in the final minutes of a game is crucial [24], as this can directly impact the outcome of a match. Similarly, measuring recovery time between repeated high-intensity efforts, such as sprinting, tackling, or pressing, is vital for understanding endurance and capacity for recovery [25].

Tests that measure aerobic capacity and lactate threshold are often used to assess endurance and recovery ability between efforts, both of which are critical for maintaining peak performance in football. Muscle buffer capacity and aerobic fitness are associated with repeated-sprint ability in women [26]. While tools exist to measure fatigue and recovery, accurately distinguishing between normal fatigue, overreaching, and true overtraining remains complex due to individual variability and limited definitive diagnostic criteria [27].

The structured 30–15 IFT effectively mimics many physical demands regarding aerobic and anaerobic capacity and is believed to provide a reasonably valid estimate of $\dot{V}O_2$ max. However, Buchheit et al. [28] stated that the 30–15 IFT cannot fully capture the complexity of specific movement patterns of a football match in terms of non-linear movements, explosive sprint actions, ball control, and decision-making. In this regard, Trecroci et al. [29] found that the 30–15 IFT does not consider elements such as neuromuscular fatigue, high-intensity efforts interspersed with lower-intensity recovery, and decision-making under fatigue, which also play a significant role in successful match performance. These elements are not fully accounted for in the 30–15 IFT, which only measures cardiorespiratory fitness without addressing tactical and psychological aspects of match play. However, independent of these specificity considerations, the 30–15 IFT shows very high test-retest reliability for maximal velocity and maximum heart rate (HRmax) [30]. Čović et al. [22] also found that the 30–15 IFT was a valid and reliable tool for assessing the physical performance of elite female football players, with high value also demonstrated by Jeličić et al. [31] for the use of 30–15 IFT in female basketball players. The authors claim that this incremental, intermittent test provides valid estimates of $\dot{V}O_2$ max and HRmax through frequent changes of direction and regular low-intensity recovery periods.

Clemente et al. [32] noted that the 30–15 IFT is particularly demanding, as it requires athletes to exercise at a high intensity, making it more challenging than similar field tests. Furthermore, Clemente et al. [32] highlighted that the 30–15 IFT is very similar to the movement demands of football training sessions and matches, which further increases its validity for the assessment of football performance, while Stanković et al. [33] confirmed its high reliability in team sport athletes.

However, there is still insufficient evidence on whether laboratory or field tests provide comparable $\dot{V}O_2$ max values. Many studies have focused on the validity and reliability of each type of test, but there is still no consensus on how these tests compare with practical, sport-specific demands [34–36]. In this regard, Mohoric et al. [37] emphasised that the results of tests under laboratory conditions may differ from a field-based context, highlighting the importance of sport-specific (field-based) tests in team sports, as treadmill tests may underestimate crucial variables used for diagnosis and training prescription.

The study compared $\dot{V}O_2$ max values obtained from the 30–15 IFT to those from the gold-standard treadmill-based incremental exercise test and evaluated the validity of the 30–15 IFT as a practical alternative to treadmill tests for elite female football players. Addressing these aims would allow practitioners to gain further insight into the potential of field testing as a valid practical alternative to laboratory testing in female elite football players and contribute to a better understanding of how effective different testing methods may be when compared using a consistent sample of elite female players.

Material and methods

Participants

Fifteen female football players (age = 24.4 ± 5.7 years, height = 166.5 ± 6.2 cm, weight = 59.9 ± 6.0 kg), all members of the Slovenian senior national team, were recruited for this study. All participants volunteered to take part following an invitation. The players were selected based on their active participation in major international competitions, including the World Cup, European qualifiers, and friendly matches. According to the McKay Classification Scale [38], all participants were categorised as elite athletes based on their participation in high-level international competitions. The sample consisted of six midfielders, four attackers and five defenders, so various outfield playing positions were represented. Participants were included in the study if they met the criteria of no injury within the six months prior to recruitment, no current musculoskeletal pain, and no previous diagnosis of chronic musculoskeletal, metabolic, pulmonary, neurological, or cardiovascular disease.

Assessment methods

All tests were conducted indoors at two different facilities, a physiology laboratory and a larger hall (with a tartan surface) at the Faculty of Sport, University of Ljubljana, Slovenia. Controlled and constant environmental conditions prevailed in both locations. In the laboratory, the temperature was 21°C and 50% humidity, and in the hall, these values were recorded as 23°C and 45%, respectively. The tests took place at the beginning of the off-season (June), outside of the regular competition schedule. All measurements with the same 15 participants were conducted randomly between 8:00 and 11:00 am, with a standardised three-day recovery period between the two tests. In addition, participants were instructed to refrain from intense physical activity 24 hours before the test, with the last exercise session taking place no less than 12 hours before the test. To ensure that participants were adequately prepared, the test procedures were explained and demonstrated in detail by experienced members of the research team. The standardised warm-up protocol included a 10-minute moderate running session followed by 5 min of dynamic stretching and ended with specific preparatory exercises tailored to the treadmill and 30–15 IFT protocols.

Anthropometric measurement

For anthropometric measurements, a vertical stand and a scale anthropometer (GPM Model 101, Zürich, Switzerland) were used to measure body mass and height to an accuracy of 0.1 kg and 0.1 cm, respectively. A further determination of body mass was performed by multifrequency bioelectrical impedance (InBody 720; Biospace Co., Ltd., Seoul, South Korea), which also has an accuracy of 0.1 kg. Fat mass, body fat percentage, skeletal muscle mass, and total body water were also determined through bioelectrical impedance using the manufacturer's internal methodology, which was previously described [39].

Incremental treadmill test

Gas exchange variables and ventilatory parameters were continuously measured throughout all tests using a metabolic cart (Quark CPET; Cosmed, Rome, Italy). Before each test, the metabolic cart was calibrated using a known gas mixture within the expected ranges of O_2 and CO_2 concentrations (16% and 5%, respectively), and airflow calibration was performed using a 3 l syringe (Cosmed, Rome, Italy). HR was also continuously recorded using a standard Polar H7 HR monitor (Polar

Electro, Kempele, Finland). After a five-minute baseline measurement while standing on the treadmill (HP Cosmos, Nussdorf, Germany), participants ran at 8 km/h at an incline of 1% to warm up [40]. The speed was then increased by 1 km/h every two minutes until volitional exhaustion. $\dot{V}O_2$ max was determined as the point at which oxygen uptake plateaued despite continued workload increases (< 2.1 ml/kg/min increase [41]). $\dot{V}O_2$ max was confirmed when a plateau in oxygen uptake was reached, the respiratory exchange ratio (RER) exceeded 1.10, the estimated HRmax was achieved, and the ventilatory equivalent for oxygen ($\dot{V}_E/\dot{V}O_2$) was greater than 35. If a plateau was not reached, participants performed a steady-state test at or above the highest workload achieved [42]. Respiratory gasses were measured breath-by-breath and averaged every five seconds [43]. The lowest running speed that elicited $\dot{V}O_2$ max for more than 30 s was defined as maximal running speed (MRS).

30–15 intermittent fitness test

Cardiorespiratory fitness was also assessed using the 30–15 IFT, which consists of intermittent, incremental shuttle runs [44]. The test began with a 30-second run at 8 km/h followed by 15 s of active recovery. Running speed increased by 0.5 km/h every 30 s. Participants ran back and forth over 40 m between two lines at a pace dictated by a pre-recorded beep, with adjustments made based on when they passed through the three-metre zone. HR was continuously monitored throughout the test using a Polar H7 HR monitor (Polar Electro, Kempele, Finland). The test was terminated if the participants could no longer maintain the required running speed or reach the three-metre zone on three consecutive occasions. The MRS was determined as the speed of the final successful stage [44]. $\dot{V}O_2$ max was estimated using the following formula [44]:

$$VO_2maxIFT\ (ml/kg/min) = 28.3 - 2.15G - 0.741A - 0.0357BM + 0.058A \times VIFT + 1.03VIFT$$

$\dot{V}O_2maxIFT$ (ml/kg/min) – maximal oxygen uptake, G – gender, A – age, BM – body mass (kg), VIFT – maximal exercise velocity (km/h)

Statistical analysis

The data were processed using SPSS 29.0 for Windows (IBM Corp., NY, USA). The analysis included descriptive statistics with mean ± standard deviation (*SD*) and 95% confidence interval (CI). Pearson's product-moment correlation coefficient (*r*) determined the relationships between associated variables. The statistical significance of the results was accepted at $p < 0.05$. The intraclass correlation coefficient (ICC) was used to assess the reliability of the individual $\dot{V}O_2$ max measurements. A two-way mixed-effects model was applied, with the measurements included as fixed effects and participant-related effects specified as random. The ICC was calculated using a consistency definition (type C), excluding between-measurement variance from the denominator to focus on between-measurement consistency. This model assumed that the interaction effect was not present as it could not be estimated [45].

Results

Table 1 provides an overview of the anthropometric characteristics of the participants.

Table 2 summarises the results of the performance tests. The mean MRS treadmill speed (MRS_Treadmill) was 13.4 km/h, and the $\dot{V}O_2$ max values of the 30–15 IFT ($\dot{V}O_2$ max_IFT) and treadmill tests ($\dot{V}O_2$ max_Treadmill) were 51.8 ml/kg/min and 47.1 ml/kg/min, respectively, indicating high aerobic fitness. The HR was similar during the treadmill and 30–15 IFT tests, indicating consistent cardiovascular responses.

Table 1. Participant demographic and anthropometric characteristics

Variables	*n*	Min	Max	Mean ± *SD*	95% CL	
					LB	UB
Age (years)	15	17.0	31.0	24.4 ± 5.7	21.5	27.3
Height (cm)	15	160.1	180.4	166.5 ± 6.2	163.0	169.9
Weight (kg)	15	52.3	75.8	59.9 ± 6.0	56.5	63.2
Skeletal muscle mass (kg)	15	23.6	33.2	27.5 ± 2.5	26.0	28.9
Body fat mass (kg)	15	6.10	16.3	10.5 ± 2.8	8.9	12.1
Body fat percentage (%)	15	10.7	22.6	17.4 ± 3.6	15.4	19.4
Body mass index (kg · m^{-2})	15	19.2	23.2	21.5 ± 1.2	20.8	22.2

LB – lower bound, UB – upper bound

Table 2. Descriptive statistics for MRS_Treadmill, MRS_IFT, $\dot{V}O_2$ max_Treadmill, $\dot{V}O_2$ max_IFT, HR_Treadmill, HR_IFT

Variables	*n*	Min	Max	Mean ± *SD*	95% CI	
					LB	UB
MRS_Treadmill (km/h)	15	11.0	16.0	13.4 ± 1.4	12.6	14.1
MRS_IFT (km/h)	15	14.0	18.0	16.0 ± 1.3	15.3	16.8
$\dot{V}O_2$ max_Treadmill (ml/kg/min)	15	41.4	52.1	47.1 ± 3.3	45.2	49.0
$\dot{V}O_2$ max_IFT (ml/kg/min)	15	37.9	57.4	51.8 ± 5.0	49.0	54.6
HR_Treadmill (bpm)	15	174.0	203.0	190.5 ± 9.8	185.8	195.0
HR_IFT (bpm)	15	176.0	205.0	191.5 ± 9.3	186.4	196.7

LB – lower bound, UB – upper bound, MRS – maximal running speed, $\dot{V}O_2$ max – maximal oxygen consumption, IFT – intermittent fitness test, HR – heart rate

Table 3. Pearson's correlation coefficients (*r*), significance levels (*p*), and number of participants (*n*)

Variables		MRS_ Treadmill (km/h)	MRS_ IFT (km/h)	$\dot{V}O_2$ max_ Treadmill (ml/kg/min)	$\dot{V}O_2$ max_IFT (ml/kg/min)	HR_ Treadmill	HR_IFT
MRS_Treadmill (km/h)	*r*	1	0.266	0.533*	0.418	0.212	0.174
	p		0.358	0.041	137	0.448	0.535
	n	15	14	15	14	15	15
MRS_IFT (km/h)	*r*	0.266	1	0.707**	0.977**	–0.256	–0.245
	p	0.358		0.005	< 0.001	0.378	0.398
	n	14	14	14	14	14	14
$\dot{V}O_2$ max_ Treadmill (ml/kg/min)	*r*	0.533*	0.707**	1	0.756**	–0.163	–0.133
	p	0.041	0.005		0.002	0.562	0.638
	n	15	14	15	14	15	15
$\dot{V}O_2$ max_IFT (ml/kg/min)	*r*	0.418	0.977**	0.756**	1	–0.260	–0.255
	p	0.137	<0.001	0.002		0.369	0.379
	n	14	14	14	14	14	14
HR_Treadmill	*r*	0.212	–0.256	–0.163	–0.260	1	0.987**
	p	0.448	0.378	0.562	0.369		< 0.001
	n	15	14	15	14	15	15
HR_IFT	*r*	0.174	–0.245	–0.133	–0.255	0.987**	1
	p	0.535	0.398	0.638	0.379	< 0.001	
	n	15	14	15	14	15	15

MRS – maximal running speed, IFT – intermittent fitness test
$\dot{V}O_2$ max – maximal oxygen consumption, HR – heart rate
* correlation is significant at the 0.05 level (2-tailed)
** correlation is significant at the 0.01 level (2-tailed)

Pearson's correlation analysis (Table 3) revealed a significant positive correlation between MRS_Treadmill and $\dot{V}O_2$ max _IFT ($r = 0.533$, $p = 0.041$) and a strong association between the $\dot{V}O_2$ max results from the two tests ($r = 0.756$, $p = 0.002$). The near-perfect correlation between $\dot{V}O_2$ max_Treadmill and MRS_IFT ($r = 0.977$, $p < 0.001$) confirms the agreement between field and laboratory measurements. The HR responses were very consistent in both tests ($r = 0.987$, $p < 0.001$). The ICC for individual $\dot{V}O_2$ max measurements was 0.689, indicating moderate agreement, and 0.816 for mean measurements, indicating strong agreement.

Discussion

The study aimed to compare the laboratory-based $\dot{V}O_2$ max running test [18, 19] with the field-based 30–15 IFT [44] in elite female national team football players. The data obtained show that the $\dot{V}O_2$ max values were consistent for both measurements, with 51.8 ml/kg/min recorded for the 30–15 IFT and 47.1 ml/kg/

min for the treadmill test. These values are also consistent with reported reference values for elite female football players, where $\dot{V}O_2$ max values are typically between 49 and 57 ml/kg/min, as reported by Datson et al. [46]. This agreement suggests that both tests assess aerobic capacity in elite female football players accurately.

Although the laboratory test values were slightly lower on the treadmill, this discrepancy is likely due to different environmental conditions and exercise protocols. Research shows that various exercise testing protocols can lead to different $\dot{V}O_2$ max results due to factors such as protocol design, duration, and intensity increases [47]. The treadmill test was performed under controlled laboratory conditions, while the 30–15 IFT took place in a gym, where slight variations in temperature and humidity may have affected performance. In addition, the exercise protocols differed considerably. Indeed, the 30–15 IFT involved intermittent training with high intensity and short recovery intervals, which is close to the demands of a football match and puts a particular strain on the cardiovascular system [21]. In contrast, the treadmill test involved continuous incremental running, which leads to a more gradual progression of fatigue in different muscle groups and may result in lower $\dot{V}O_2$ max values. However, it is important to note that while the 30–15 IFT is designed to assess cardiovascular fitness, it does not fully replicate all external load factors encountered in a football game, such as tackling or positional demands.

The secondary aim of this study was to evaluate the practicality of the 30–15 IFT as a reliable alternative to the laboratory treadmill test for $\dot{V}O_2$ max determination in elite female football players. The field test showed high validity, with a Pearson correlation of 0.756 ($p = 0.002$) between the $\dot{V}O_2$ max values determined during the 30–15 IFT and those of the treadmill test. This correlation was statistically significant and indicates that the 30–15 IFT can provide an accurate estimate of $\dot{V}O_2$ max (Table 3). These findings align with previous studies demonstrating 30–15 IFT as a valid measure of cardiorespiratory fitness in a variety of athletes. In particular, Buchheit et al. [21] highlighted two decades of research demonstrating the applicability of the test in various sports, while Čović et al. [22] confirmed its reliability and validity in female football players. In addition, Valladares-Rodríguez et al. [24] demonstrated the usefulness of the test in male and female professional futsal players, further supporting its versatility. In particular, a very strong correlation of 0.977 ($p < 0.001$) was found between the MRS achieved in the 30–15 IFT and the $\dot{V}O_2$ max values measured with the treadmill test. In addition, a strong, positive correlation ($r = 0.987$, $p < 0.001$) was found between HR during the treadmill test and the 30–15 IFT, further supporting the validity of the test.

Practical implications

The results of this study have significant practical implications for coaches and practitioners working with elite female football players, particularly in environments where laboratory-based testing is not available. The study demonstrates that the 30–15 IFT is a valid and practical alternative for assessing cardiorespiratory fitness in the field. This is particularly valuable for coaches who require efficient on-field testing methods to monitor player fitness without the need for specialised laboratory facilities. Maintaining a high level of cardiorespiratory fitness is crucial for optimal endurance, as it enhances the ability to sustain high-intensity efforts and recover efficiently during competitive matches and training. Since football requires frequent high-intensity actions, interspersed with short recovery periods, coaches can use the 30–15 IFT results to effectively track the fitness levels of players and thus make data-driven decisions to optimise training programmes and ensure they are tailored to the specific demands of the sport.

The observed variability in running speeds between players underscores the importance of personalised fitness interventions. Individual factors, such as training history, fitness level, and position-specific requirements, must be taken into account when developing training strategies. In particular, national team players, who usually play at elite-level international clubs, may have a different fitness profile than regular first-division club players. Mäkiniemi et al. [12] demonstrated that national team players are often exposed to more intense and varied fitness demands due to the higher level of competition and frequency of international matches. These special circumstances can lead to different training loads and recovery protocols than for first-division players, making it important for coaches to adapt training programs accordingly. The strong correlation between HR responses in both the treadmill test and the 30–15 IFT is crucial for assessing the validity of the field test and indicates that HR can also be used as a reliable surrogate for $\dot{V}O_2$ max, allowing coaches to estimate fitness levels in field settings without requiring complex laboratory equipment. This correlation further supports the practical value of the 30–15 IFT, making it a viable option for ongoing fitness assessments, especially in resource-limited settings.

Limitations

Although this study has provided essential insights, several limitations must be considered. The relatively small and homogenous sample may limit the generalisability of the results to a larger and more varied population of female football players. In this regard, future studies should examine such results in larger heterogeneous samples to ensure their robustness across different playing levels. However, the objective of this particular study was to assess the results explicitly in elite-level athletes, and the findings thus remain internally valid. With regard to future studies, the development of a combination of field-based tests, such as the 30–15 IFT, in conjunction with other performance measures, which may include sprint performance and agility tests, would be a worthwhile avenue for further exploration. Such studies would fully represent all factors involved in the game of football.

Conclusions

The study confirmed that the 30–15 IFT is a valid and practical method for measuring cardiorespiratory fitness in elite female football players, making it a viable alternative to the laboratory-based treadmill test. Previous studies support this conclusion (44), though this is one of the few that have validated the 30–15 IFT in elite female national team football players. The results provide valuable insights into the practical application of different testing methods to assess and monitor the performance of elite female athletes and provide important guidance for coaches and sports scientists in optimising performance evaluation.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of the Faculty of Sport, University of Ljubljana (approval No.: 033-6/2024-56).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Conflict of interest

The authors state no conflict of interest.

Disclosure statement

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