

## ORIGINAL RESEARCH

### Integrated readiness monitoring based on post-competition fatigue in team sports: A longitudinal study comparing male and female athletes

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#### Abstract

The study aimed to assess the utility of a fatigue-monitoring protocol for determining athletes' readiness post-competition and to present sex-related variation in its use. Methods included a subjective assessment of specific dimensions of perceived readiness (dRIs) and an objective evaluation of the physical readiness (RDs). dRIs evaluated fatigue upon waking up, sleep quality, mood, and muscle soreness, while RDs consisted of 3 field tests. Twenty-one male and 23 female athletes were tested 4 days per week, starting from the match day (MD): MD+2, MD+3, MD+5. Results indicated no significant differences in dRIs among females, whereas for males, fatigue upon waking was lower at MD+2, MD+3, and MD+5 than at MD, and muscle soreness was higher at MD+5 than on the other days. For RDs, only a significant difference in adductor strength was found in females between MD and MD+2, as well as between MD+2 and MD+3, whereas no notable changes were evidenced in males. Between sexes, the dRIs comparison showed significant differences on MD; for RDs, a difference was found only for the Adductor Squeeze Test on MD+3. In conclusion, sex differences in the utility of dRIs have been noted: they appear less suitable in females, whereas in males they reflect the expected fatigue pattern. Instead, in terms of RDs, they seemed limited in fatigue detection in both sexes; they serve as useful tools for assessing physical readiness with eventual differences in ROM and strength.

#### Keywords:

fatigue monitoring, load management, performance, readiness for exercise, recovery, team sport

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#### Introduction

Rugby is a physically demanding contact sport that has gained popularity around the world in recent years, becoming one of the most widely played and watched. It is an intermittent team sport, with an average intensity similar to other team sports (~70-80% VO<sub>2</sub>max), in which high-intensity phases of the game (high-intensity running, rucking, scrummaging, tackling, etc.) alternate with lower-intensity phases (low-intensity running, walking, etc.) for a total

of 80 minutes, divided into two 40-minute halves with a 10-minute break in between (Read et al., 2017; Twist & Highton, 2013). These game's demands, together with the high number of collisions and repeated eccentric muscle contractions associated with acceleration and deceleration, lead to an increase in markers of muscle damage and acute neuromuscular and perceptual fatigue after matches, which can last up to several days after the competition (Roe, 2016; Twist & Highton, 2013) and it means

that the inherent risks of injury are substantial (Hulin et al., 2016). The incidence of injury in this sport has been widely reported in literature, with values ranging from 5.95/1000 to 99.5/1000 hours of play in amateur rugby and approximately 81/1000 in professional rugby. While comprehensive injury-monitoring and prevention programs have been implemented in professional play, similar strategies are needed in amateur play (Yeomans et al., 2018).

Typically, during the regular season, senior athletes play one game per week, which likely provides sufficient time for complete recovery between matches. Consequently, S&C (Strength and Conditioning) coaches systematically monitor players' recovery status and aim to manage fatigue by making daily adjustments to training loads, as fatigue accumulation is believed to negatively affect players' wellbeing and performance (Johnston et al., 2013). However, the time course of post-match recovery is highly variable among individual players, potentially leaving some players insufficiently recovered on match day (West et al., 2014). Therefore, to ensure that athletes are ready to perform, daily fatigue monitoring is often recommended (Ramírez-López et al., 2022). The entity of fatigue induced by matches and the subsequent recovery kinetics have been studied previously. For example, the decrease in neuromuscular function (NMF) assessed through counter-movement jumps (CMJ) can persist up to 48 hours after the match (Ramírez-López et al., 2020b; Roe, 2016). Well-being has also been recommended for studying players' responses to matches in both senior and elite youth populations, and its decline has been observed to persist for up to 72 hours after the match (Johnston et al., 2013; Roe, 2016; Saw et al., 2016).

Athlete self-report measures (ASRMs) are the most widely used method for monitoring fatigue in high-level sport systems (Taylor et al., 2012) because they are generally non-invasive, easy to

administer, and may be more sensitive to changes in training and post-match loads than other commonly used objective assessments (Saw et al., 2016). However, the subjective nature of these questionnaires must be considered, and therefore, they have a greater margin of error.

### Aetiology of Fatigue

Fatigue is the decline in physical performance induced by an increase in the actual or perceived difficulty of a task. It is not the failure of the demand or the moment when the muscles get exhausted, but it refers to the inability of the muscles to maintain the required level of strength/power during an exercise, and it develops gradually immediately after the beginning of an intense physical task (Starling & Lambert, 2018). The increase in energy produced during exercise disrupts the body's internal homeostasis, leading to the accumulation of certain metabolites within muscle fibres and fatigue. Fatigue occurs because one or more physiological processes that allow contractile proteins to generate force are compromised, and the site of the damage depends on the task being performed (Enoka & Duchateau, 2008). This phenomenon is known as "task-dependency", and it refers to the fact that there is no single cause that explains the aetiology of fatigue, as it is considered a gradual process involving various complex physiological changes inside and outside the muscle (Tornero-Aguilera et al., 2022).

The aetiology of fatigue arises from two main pathways: the central nervous system through central fatigue, or the peripheral nervous system through peripheral fatigue. Central fatigue is defined as a decrease in voluntary muscle activation, directly related to reduced frequency and synchronisation of motor neurons and reduced information transmission from the motor cortex, which attenuates performance or even leads to cessation of activity. Peripheral fatigue is defined as a decrease in the effectiveness of the neuromuscular

junction and processes beyond it, including metabolic and biochemical changes within the muscle that diminish the contractile strength of muscle fibres and alter the mechanisms of transmission of muscle action potentials.

Fatigue is influenced by factors such as sex, which affects men and women differently. Women have greater lipid oxidation efficiency but lower anaerobic lactacid pathway efficiency than men. The interpretation of effort and stress differs when faced with the same workload, and here perception is greater for women. Consequently, fatigue perception is greater in women (Tornero-Aguilera et al., 2022). Fatigue can also be influenced by the type of stimulus (voluntary or electrical), the type of contraction (isometric, isotonic, intermittent, or continuous), the duration, the frequency, and the intensity of the task, and even by the type of muscle.

Additionally, physiological state, training status, and environmental conditions can significantly influence fatigue (Halson, 2014). Personal problems, anxiety, and stress are likewise associated with different patterns of brain activation and central nervous system weariness. External factors, such as sleep deprivation, can also modify the subjective perception of fatigue. Thus, these factors can result in increased central fatigue (Tornero-Aguilera et al., 2022) and decreased ability to respond promptly and responsively to external stimuli.

It is essential for rugby and S&C coaches to understand the mechanisms and aetiology of fatigue in order to prescribe an appropriate training load to reduce the risk of non-functional overreaching, illness, or injury, and to maintain the athlete's optimal physiological and psychological wellbeing (Halson, 2014).

### **Monitoring Training Load and Fatigue**

Monitoring training load can provide a scientific explanation for changes in performance and enable an appropriate planning of training loads. Understanding players' responses to load and fatigue status

after games throughout the season is necessary to determine which athletes are ready for matches and to avoid injuries, performance declines and overtraining syndromes. This requires an appropriate battery of tests that allows coaches to make decisions based on each athlete's health status. Although there is much scientific evidence for valid and reliable test batteries for monitoring load and fatigue, the application environment must always be taken into account in order to select those tests that are most suitable and easily feasible in the context in which they are used (Halson, 2014; Twist & Highton, 2013).

A review of the scientific literature suggests that the best test for assessing fatigue in terms of ecological validity is a maximal-effort test that reproduces the conditions of the athlete's competition. However, there are numerous complications with this type of task in athletes, especially in a team-sport context, where non-reproducible external factors related to the opposing team's behaviour are present. Additionally, maximal tests could exacerbate the athlete's existing fatigue, which can be problematic during the competitive phase of the season. Therefore, performance monitoring is generally based on indirect markers of maximal performance and/or relevant psychological and physiological characteristics (Taylor et al., 2012).

For example, tests that measure neuromuscular capacity, such as jump tests (CMJ/SJ), sprint tests, or tests with isokinetic and isoinertial dynamometers, are preferred due to their simplicity of administration and the minimal additional fatigue they induce in the athlete. Jump tests reflect the lengthening-shortening capacity of the lower limb muscles and provide useful data to assess muscle fatigue, whereas sprint tests provide information on movement-specific fatigue, as these actions are typically compromised after prolonged intermittent activity, such as a rugby match (Twist & Highton, 2013).

A relatively large number of studies have examined the biochemical, hormonal, and immunological responses to physical exercise, with analyses performed on blood or saliva. For instance, analysis of serum creatine kinase activity, a marker of muscle damage (Lee et al., 2017), has been shown to be a popular method for assessing fatigue and acute recovery after a match, as sample collection and analysis are easy to implement. In addition, salivary cortisol and testosterone levels have been shown to be related to athletes facing a state of overreaching. However, the usefulness of these measures for quantifying internal load on a regular basis has not yet been examined, partly because these procedures are expensive, time-consuming, and quite impractical in sports environments, especially for team sports (Drole et al., 2025).

### Readiness Monitoring

It is essential for coaches to have a training periodisation, but it is even more important to adapt it based on how the athlete is coping with the demands of training or a match. To do this effectively, coaches need information on each athlete's recovery ability in response to various training stressors, and they often rely on “self-report” questionnaires that assess perceived changes in muscle soreness, fatigue, sleep quality and quantity, and other psychosocial factors. There are several tools for assessing perceived fatigue, of which the most popular are tailor-made forms such as the Profile of Mood States questionnaire (POMS), the Daily Analysis of Life Demands for Athletes questionnaire (DALDA), the Recovery-Stress Questionnaire for Athletes (REST-Q Sport), and the Total Quality Recovery scale (TQR). According to Taylor et al. (2012) many professionals in the field of elite sport, questionnaires should be shorter and better targeted. Therefore, several forms have been developed over the years, generally consisting of 5-12 questions that use a simple 5-, 7-, or 10-point Likert scale to

score the response, with the sum of the questions indicating the overall athlete's wellbeing. Although shorter questionnaires are more time-efficient, it is important to be aware of their reduced sensitivity for quantifying fatigue, as they contain fewer, more general questions (Twist & Highton, 2013). The most frequently investigated aspects in “self-report” questionnaires are perceived muscle soreness (DOMS), sleep duration and quality, and perceptions of fatigue and wellbeing (Taylor et al., 2012).

In rugby, players typically report their mood, stress levels, energy, sleep, and nutrition, as well as feelings of soreness in the upper body, quadriceps, hamstrings, groin, and calves (Gabbett, 2016). Sleep is recognised as an essential part of recovery and is central to optimal athletic performance, wellbeing, and the reduction of injuries and illness. The American Academy of Sleep Medicine (AASM; Watson et al., 2015) recommends that athletes benefit from more sleep than the 7/8 hours per night recommended for the general population, due to their exposure to high-intensity training and competition (Ramírez-López et al., 2020a).

Questionnaires can be a relatively simple and inexpensive way to assess athletes' fatigue and readiness to train. However, because they are based on subjective information, athletes can manipulate the data and/or over- or underestimate their training load. It is also important to consider the frequency of administration and its length to maximise athlete adherence and avoid the “boredom” of completing the questionnaire (Halson, 2014). In light of the evidence highlighted in the literature, there is a clear need to develop practical monitoring approaches capable of identifying periods of reduced readiness in athletes. In this study, particular attention was given to identifying periods of reduced readiness following competition, referred to operationally as the “red zone”, which represents a phase of increased fatigue typically occurring within the first days after match exposure.

### Purpose

The main objective of this investigation was to evaluate whether monitoring four specific dimensions (fatigue upon waking, sleep quality, mood, and muscle soreness) can help identify athletes' readiness to compete in both male and female athletes. In this context, the monitoring protocol was designed to generate an integrated score to identify the "red zone," operationally defined as a phase of increased fatigue and reduced readiness occurring approximately within the first 2 days after the match (MD+2). This phase is characterised by a significant deterioration in test scores relative to the athlete's best individual value recorded during the monitoring period, indicating a temporary reduction in perceived or functional readiness.

Secondly, this study aimed to examine sex differences in using the same readiness-monitoring approach, particularly by accounting for the menstrual cycle in women, which can alter athletes' readiness depending on the phase they are in.

The hypothesis of this study was that monitoring four specific readiness-related dimensions, as determined by this protocol, can help identify an athlete's readiness for competition. More specifically, athletes were expected to report higher readiness scores on match day (MD), indicating optimal conditions for the competition. Conversely, lower readiness values were expected approximately two days after the match (MD+2), reflecting fatigue resulting from match participation.

### Methods

This research consisted of a prospective, longitudinal, observational study to analyse post-match recovery profiles.

### Participants

The group that took part in the project consisted of 35 males (age:  $26.3 \pm 4.6$  yrs, weight:  $98.29 \pm 16.91$  kg, height:  $182.16 \pm 6.70$  cm) playing in the second top Italian men's rugby league, Serie A and 27

females (age:  $24.85 \pm 2.97$  yrs, weight:  $70.70 \pm 9.91$  kg, height:  $168.04 \pm 7.91$  cm) playing in the top women's league, Serie A Elite.

However, the final sample analysed was smaller: only 21 males and 23 females were declared valid, as some data were deemed insufficient for various reasons. For example, if some players did not complete a training session or skipped parts of the questionnaire, they were discarded, and if the collected data were significantly different from the average, it indicated an error in the sample collection.

### Ethical Approval

This research was conducted in accordance with the principles of the Declaration of Helsinki. Before data collection, participants received verbal and written explanations of the study and provided written informed consent to complete the self-reported questionnaires. Data were collected through an electronic questionnaire (Google Forms), where participants were asked to identify by using a personal ID. All data were later analysed in aggregate.

The study protocol was reviewed and approved by the University of Milan's Ethics Review Committee (approval number: 19/26; approved in 2026). Data confidentiality and protection were ensured throughout the study: access to the database was restricted to the research team, and only personal ID numbers were collected. No identifiable information was retained, and no individual data were shared with the participating sports clubs. Data were stored securely and will be retained in accordance with institutional data protection guidelines.

### Study Design

This study considered two distinct periods of the competitive season (November-December and February-March), each lasting four weeks, for a total of eight weeks, where matches were played on Sundays. For each period, the first week was to familiarise with the protocol and to record the personal best (PB), and in the last three

weeks, there were the matches. The players were monitored four days per week before each training session and each match to monitor their perceived and physical readiness.

The days on which the tests were carried out were classified as Match Day (MD), Match Day + 2 (MD+2, rugby session on the field 48 hours after the match), Match Day +3 (MD+3, rugby session on the field 72 hours after the match), and Match Day +5 (MD+5, team run 120 hours after the match).

The chosen methodology involved a two-part monitoring approach: a subjective assessment of specific dimensions of the athlete's perceived readiness (dRIs) and an objective assessment of physical readiness (RDs) through evaluations of strength and flexibility (Range of Motion, ROM). For both assessments, a single electronic questionnaire was created in Google Forms (Google, CA, USA), which participants were required to complete on their own cell phones to avoid any influence from other team members. The aim was to obtain data to calculate the state of readiness and to assess differences between rest and training days (Ramírez-López et al., 2022) and, similarly, to obtain indications of differences in strength and ROM. A practical monitoring framework was adopted to identify periods of increased fatigue and reduced readiness, occurring within approximately the first two days after the match (MD+2), which have been called "red zones", characterised by a significant deterioration of the test results relative to the athlete's best individual value recorded during the monitoring period.

## Research Materials and Procedures

### *Subjective Readiness Protocol*

The first part was a self-report questionnaire where the athlete was asked to answer four questions concerning: fatigue upon waking up (FW), sleep quality (SQ), mood (Mo) and DOMS, with each question rated on a 5-point Likert scale (1-

5), where 1 was the minimum and 5 the maximum, with increments of one point, as described in previous studies (McLean et al., 2010; Ramírez-López et al., 2020a).

Then the total dRIs score was obtained by summing the four scores, so the minimum possible score was 4, and the maximum was 20. Finally, for each question, a fatigue index (FWi, SQi, Moi, DOMSi), was calculated by dividing the score obtained on the day of competition or training by the personal best (PB) scored. The index ranged from 0 to 1, with 1 representing the athlete's personal condition. An aggregated four-dimensional readiness index (4-dRi) was then calculated as the arithmetic mean of the four indices to provide an overall indicator of readiness over time. Within this framework, the "red zone" condition was identified by examining reductions in the 4-dRi occurring approximately two days after the match (MD+2) relative to the athlete's best individual value recorded during the monitoring period.

### *Objective Readiness Protocol*

The second part consisted of three field tests: the Adductor Squeeze Test (AST), the Sit and Reach Test (SRT), and the Knee-to-Wall Test (KTW). Unlike the subjective part, the answers obtained were relatively consistent: the maximum score obtained in mmHg (millimetres of mercury) for AST, the maximum score obtained in cm (centimetres) for SRT, and the maximum scores obtained in cm (centimetres) for KTW, either right (KTWR) or left (KTWL) ankles.

The Adductor Squeeze is a test that indirectly measures the maximum strength of the thigh adductor muscles using a sphygmomanometer to quantify the pressure generated by compressing the air chamber between the two thighs. The athlete must lie supine, maintaining a 90° angle at the hips and knees as shown in Figure 1a, and place the air chamber of the sphygmomanometer between the knees. Then, using the valve, the athlete set the

pressure to 100 mmHg and executed a maximum adduction of the thighs, compressing the air chamber with as much force as possible, trying to maintain the contraction for 5 seconds, and reported the maximum mmHg value reached in the Google form. This test has been chosen because hip and groin injuries are a

common problem in team sports, particularly those involving running, changes of direction, and kicking. In these areas, adductor compression tests are often used to diagnose, monitor, and prevent the risk of developing groin pain (Hodgson et al., 2015).



Figure 1a. Adductor Squeeze Test

The Sit and Reach is a validated test of hamstring extensibility, chosen for its simplicity of application in a team-sport context (Mayorga-Vega et al., 2014). The athlete sat on the ground with his legs extended, leaning against the wall with his buttocks and shoulders, a centimetre-graduated scale placed under him. When ready, while maintaining the starting position of the legs, he bent his torso forward as far as possible, keeping his arms extended and, with the hands overlapping in correspondence with the graduated scale,

he touched the point furthest away from him, trying to maintain this position for 3", (Figure 1b). Then, he recorded the cm reached on the Google form. The importance of good hamstring extensibility, along with adequate strength, is in reducing the risk of muscle injuries in this area (Edouard et al., 2022). Consequently, in these athletes, who perform weight training and sprints in all their training sessions, monitoring hamstring stretching status is an interesting tool for obtaining specific information useful for injury prevention.



*Figure 1b.* Sit and Reach Test

The Knee-to-Wall test measures ankle joint range of motion and can be used as a continuous assessment of ankle dorsiflexion. The athlete stood facing the wall in a lunge position, bringing the knee of the rear leg to the ground and moving the foot of the opposite leg forward, next to the graduated scale, keeping the hip and knee angles at  $90^\circ$ . Next, while performing ankle dorsiflexion, he brought the frontal knee forward until it touched the wall without ever lifting the heel off the ground, and once the wall was reached, he measured the distance in cm between the toes on the ground and the wall (Figure 1c). After performing the test

with both limbs, he recorded the measurements obtained as answers on the Google form (Powden et al., 2015). This test has been chosen based on the widespread consensus that limited ankle dorsiflexion contributes to the development of conditions such as patellofemoral knee syndrome, foot overpronation, and plantar fasciitis, which can be risk factors for common lower limb injuries. The practice of rugby, especially in contact situations, involves the lower limbs, leading to stiffness in these areas; therefore, it is very likely that rugby players experience dorsiflexion stiffness.



Figure 1c. Knee to Wall Test

Finally, for each dRIs question, a fatigue index, with a value from 0 to 1, was calculated; for each RDs test, the score obtained on the day of competition or training was divided by the participant's PB score (ASTi, SRTi, KTWi-R, KTWi-L).

### Data Analysis

A longitudinal analysis was chosen to investigate longer-term events, comparing data from both phases of the study during the championship. The statistical tests were performed using JASP (Jeffreys's Amazing Statistics Program, version 0.95.4).

Descriptive statistics were calculated for each variable at each time point relative to match day (MD, MD+2, MD+3, MD+5) and are presented as median, mean, standard deviation, interquartile range (IQR), minimum, and maximum values. The normality of the data distribution was

assessed using the Shapiro–Wilk test, which indicated significant deviations from normality ( $p < .001$ ). Therefore, linear mixed-effects models (LMMs) were used to analyse the effects of time points relative to match day on the subjective and objective readiness variables. A separate model was fitted for each variable, yielding 9 models for females and 9 for males.

For all models, the athlete's identity was included as a random effect to account for repeated measurements within participants. Time points relative to match day (MD, MD+2, MD+3, MD+5) were included as a fixed effect. For the sex-comparison analysis, Sex and the Sex  $\times$  Time interaction were also included as fixed effects. Model terms were tested using the Satterthwaite approximation for degrees of freedom, and Type III sums of squares were used. When significant effects

were detected, pairwise contrasts were performed with Holm-adjusted p-values to control for multiple comparisons. The level of statistical significance was set at  $p < 0.05$ .

Additionally, data were collected across six match weeks for each team, organised into two regular-season periods, each comprising a maximum of three consecutive matches. Prior to data collection, athletes were familiarised with the monitoring protocol to ensure consistent and reliable responses. Athletes who did not complete a sufficient portion of the monitoring protocol (i.e., fewer than 10 valid observations across the monitoring period, corresponding to more than two full match weeks) were excluded from the analysis to ensure adequate data for reliable model estimation. The remaining dataset, therefore, included repeated observations from the same athletes across multiple monitoring cycles. Missing data within these observations were handled using restricted maximum likelihood (REML) estimation within the LMM framework. The repeated structure of the data was further accounted by including athlete identity as a random effect.

## Results

The statistical analysis conducted with JASP described changes in the dependent variables across time points relative to match days and differences between females and males. Detailed descriptive tables (Table S1 and Table S2) and the full panel plots (Figure S1-S2-S3) are provided in the Supplementary Materials, whereas the main findings are presented in the tables described in the following sections.

### Subjective Readiness Monitoring

The effects of match days on subjective readiness variables were analysed using linear mixed-effects models with athletes included as a random effect, comparing time points relative to the match day (MD, MD+2, MD+3, and MD+5).

In the female group, no clear changes were observed across the analysed time points for any subjective variable. FWi, SQi, Moi, DOMSi, and the aggregated four-dimensional readiness index (4-dRi) remained relatively stable from MD to post-match assessments (Table 1a-1e).

*Table 1a.* Pairwise contrasts between match days derived from the linear mixed model for the FWi female

	Estimate	SE	df	t	p†
MD vs MD + 2	0.014	0.028	23.286	0.519	1.000
MD vs MD+3	0.009	0.028	18.509	0.334	1.000
MD vs MD+5	0.049	0.025	38.137	1.961	.343
MD+2 vs MD+3	-0.005	0.026	45.956	-0.198	1.000
MD+2 vs MD+5	0.035	0.029	20.377	1.201	.974
MD+3 vs MD+5	0.040	0.027	33.873	1.483	.736

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed no significant main effect of Match Day ( $F(3, 28.68) = 1.45, p = .248$ ).

*Table 1b.* Pairwise contrasts between match days derived from the linear mixed model for the SQi female

	Estimate	SE	df	t	p†
MD vs MD + 2	-0.030	0.026	23.767	-1.163	1.000
MD vs MD+3	-0.052	0.024	349.685	-2.194	.173

*Table 1b.* (continued)

	Estimate	SE	df	t	p†
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MD vs MD+5	-0.003	0.023	360.339	-0.127	1.000
MD+2 vs MD+3	-0.021	0.026	31.723	-0.823	1.000
MD+2 vs MD+5	0.027	0.026	30.103	1.051	1.000
MD+3 vs MD+5	0.049	0.023	369.991	2.075	.194

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed no significant main effect of Match Day (F (3, 56.30) = 2.12,  $p = .108$ ).

Table 1c. Pairwise contrasts between match days derived from the linear mixed model for the Moi female

	Estimate	SE	df	t	p†
MD vs MD + 2	0.011	0.023	318.435	0.469	1.000
MD vs MD+3	-0.023	0.023	24.794	-0.997	1.000
MD vs MD+5	0.004	0.024	40.597	0.157	1.000
MD+2 vs MD+3	-0.034	0.024	95.834	-1.438	.921
MD+2 vs MD+5	-0.007	0.024	74.728	-0.298	1.000
MD+3 vs MD+5	0.027	0.023	144.472	1.151	1.000

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed no significant main effect of Match Day (F (3, 69.37) = .796,  $p = .500$ ).

Table 1d. Pairwise contrasts between match days derived from the linear mixed model for the DOMSi female

	Estimate	SE	df	t	p†
MD vs MD + 2	0.039	0.023	113.129	1.672	.389
MD vs MD+3	0.015	0.022	293.198	0.690	.909
MD vs MD+5	0.055	0.022	204.952	2.530	.073
MD+2 vs MD+3	-0.024	0.023	189.757	-1.034	.907
MD+2 vs MD+5	0.017	0.022	260.607	0.749	.909
MD+3 vs MD+5	0.040	0.022	340.177	1.849	.327

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed no significant main effect of Match Day (F (3, 208.58) = 2.44,  $p = .065$ ).

Table 1e. Pairwise contrasts between match days derived from the linear mixed model for the 4-dRi female

	Estimate	SE	df	t	p†
MD vs MD + 2	0.010	0.016	61.688	0.620	1.000
MD vs MD+3	-0.014	0.016	166.637	-0.877	1.000
MD vs MD+5	0.026	0.016	94.397	1.646	.515
MD+2 vs MD+3	-0.024	0.017	47.818	-1.437	.629
MD+2 vs MD+5	0.016	0.017	27.523	0.929	1.000
MD+3 vs MD+5	0.039	0.015	343.427	2.548	.068

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed no significant main effect of Match Day (F (3, 65.88) = 2.30,  $p = .085$ ).

In the male group, the subjective readiness showed a clearer time-related

variation. A significant effect of time point was observed for FWi (F(3, 27.55)=11.35,

$p < .001$ ), with lower FWi values at MD compared with MD+2, MD+3, and MD+5 (Holm-adjusted  $p \leq .002$ ), indicating a worse fatigue perception at MD relative to the subsequent assessments (Table 2a). DOMSi also varied significantly over time ( $F(3, 23.13) = 8.45, p < .001$ ), with the muscle soreness being higher at MD+5 compared with earlier time points (Table 2d). The 4-dRi showed a significant effect of time point ( $F(3, 17.16) = 5.77, p = .006$ ), with

higher readiness at MD compared with MD+2, MD+3, and MD+5 (Holm-adjusted  $p \leq .022$ ) (Table 2e). No meaningful time-related changes were detected for SQi or Moi within the male group (Table 2b and 2c). The decrease in readiness observed around MD+2 corresponds to the period, within the monitoring framework adopted in this study, referred to operationally as the “red zone”.

*Table 2a.* Pairwise contrasts between match days derived from the linear mixed model for the Fwi male

	Estimate	SE	df	t	p†
MD vs MD + 2	0.102	0.027	42.025	3.738	.002
MD vs MD+3	0.124	0.024	71.753	5.156	< .001
MD vs MD+5	0.109	0.026	47.564	4.256	< .001
MD+2 vs MD+3	0.022	0.029	21.491	0.767	1.000
MD+2 vs MD+5	0.007	0.026	18.030	0.263	1.000
MD+3 vs MD+5	-0.015	0.028	19.798	-0.550	1.000

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed a significant main effect of Match Day ( $F(3, 27.55) = 11.35, p < .001$ ).

*Table 2b.* Pairwise contrasts between match days derived from the linear mixed model for the SQi male

	Estimate	SE	df	t	p†
MD vs MD + 2	0.033	0.032	19.111	1.014	1.000
MD vs MD+3	0.052	0.032	17.527	1.639	.595
MD vs MD+5	0.007	0.026	18.259	0.285	1.000
MD+2 vs MD+3	0.020	0.021	45.098	0.922	1.000
MD+2 vs MD+5	-0.025	0.023	26.833	-1.121	1.000
MD+3 vs MD+5	-0.045	0.025	16.979	-1.806	.532

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed no significant main effect of Match Day ( $F(3, 25.58) = 1.24, p = .316$ ).

*Table 2c.* Pairwise contrasts between match days derived from the linear mixed model for the Moi male

	Estimate	SE	df	t	p†
MD vs MD + 2	0.078	0.038	20.351	2.028	.326
MD vs MD+3	0.077	0.044	18.786	1.741	.326
MD vs MD+5	0.029	0.034	20.200	0.856	.804
MD+2 vs MD+3	$-3.965 \times 10^{-4}$	0.027	54.509	-0.015	.988

*Table 2c. (continued)*

	Estimate	SE	df	t	p†
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MD+2 vs MD+5	-0.049	0.025	132.982	-1.941	.326
MD+3 vs MD+5	-0.048	0.027	29.349	-1.814	.326

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed no significant main effect of Match Day ( $F(3, 46.01) = 1.97, p = .132$ ).

Table 2d. Pairwise contrasts between match days derived from the linear mixed model for the DOMSi male

	Estimate	SE	df	t	p†
MD vs MD + 2	0.054	0.023	52.736	2.307	.100
MD vs MD+3	0.060	0.027	18.915	2.267	.100
MD vs MD+5	0.134	0.027	19.777	4.968	< .001
MD+2 vs MD+3	0.006	0.027	23.006	0.236	.815
MD+2 vs MD+5	0.081	0.025	25.926	3.213	.017
MD+3 vs MD+5	0.074	0.031	19.184	2.394	.100

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed a significant main effect of Match Day ( $F(3, 23.13) = 8.45, p < .001$ ).

Table 2e. Pairwise contrasts between match days derived from the linear mixed model for the 4-dRi male

	Estimate	SE	df	t	p†
MD vs MD + 2	0.068	0.021	16.699	3.180	.022
MD vs MD+3	0.075	0.019	12.809	3.860	.010
MD vs MD+5	0.074	0.020	19.303	3.786	.007
MD+2 vs MD+3	0.007	0.016	20.529	0.447	1.000
MD+2 vs MD+5	0.006	0.016	14.690	0.376	1.000
MD+3 vs MD+5	-0.001	0.015	13.584	-0.080	1.000

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed a significant main effect of Match Day ( $F(3, 17.16) = 5.77, p = .006$ ).

To provide a concise overview of the main models observed, Table 3 summarises them.

Table 3. Summary of the main patterns observed in subjective and objective readiness variables across time points relative to match day (MD, MD + 2, MD + 3, MD + 5) in female and male groups

Variable	Female group	Male group
Fwi	No clear time-related changes	Lower values at MD vs MD+2, MD+3, MD+5
SQi	No clear time-related changes	No clear time-related changes
Moi	No clear time-related changes	No clear time-related changes
4-dRi	No clear time-related changes	Higher values at MD+5 vs MD and MD+2
ASTi	Differences between MD vs MD+2 and MD+2 vs MD+3	No clear time-related changes
SRTi	No clear time-related changes	No clear time-related changes
KTWi-R	No clear time-related changes	No clear time-related changes
KTWi-L	No clear time-related changes	Difference between MD+3 and MD+5

## Objective Readiness Monitoring

The effects of time points relative to match days (MD, MD+2, MD+3, and MD+5) on objective readiness variables were analysed using linear mixed-effects models with athletes included as a random effect.

In the female group, a different pattern emerged. A significant effect of time point was observed for ASTi ( $F(3, 54.72) = 4.45$ ,

$p=.007$ ), with differences between MD and MD+2 and between MD+2 and MD+3, indicating a transient change in adductor strength around the early post-match assessments (Table 1f). No meaningful changes were detected for SRTi, KTWi-R, or KTWi-L, which remained stable across the analysed time points (Table 1g-1i).

*Table 1f.* Pairwise contrasts between match days derived from the linear mixed model for the FWi female

	Estimate	SE	df	t	p†
MD vs MD + 2	0.049	0.014	24.823	3.486	.011
MD vs MD+3	0.018	0.013	38.612	1.445	.313
MD vs MD+5	0.020	0.011	75.011	1.744	.256
MD+2 vs MD+3	-0.031	0.011	85.489	-2.758	.036
MD+2 vs MD+5	-0.029	0.012	32.029	-2.443	.081
MD+3 vs MD+5	0.002	0.011	97.610	0.171	.864

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed a significant main effect of Match Day ( $F(3, 54.72) = 4.45, p = .007$ ).

*Table 1g.* Pairwise contrasts between match days derived from the linear mixed model for the SRTi female

	Estimate	SE	df	t	p†
MD vs MD + 2	0.014	0.010	145.891	1.434	.922
MD vs MD+3	$-3.231 \times 10^{-4}$	0.011	43.783	-0.030	1.000
MD vs MD+5	0.003	0.010	237.132	0.328	1.000
MD+2 vs MD+3	-0.015	0.011	23.286	-1.307	1.000
MD+2 vs MD+5	-0.011	0.010	68.141	-1.108	1.000
MD+3 vs MD+5	0.003	0.011	53.305	0.327	1.000

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed no significant main effect of Match Day ( $F(3, 57.69) = .855, p = .470$ ).

*Table 1h.* Pairwise contrasts between match days derived from the linear mixed model for the KTWi-R female

	Estimate	SE	df	t	p†
MD vs MD + 2	-0.010	0.015	41.802	-0.671	1.000
MD vs MD+3	-0.006	0.015	27.414	-0.428	1.000
MD vs MD+5	-0.010	0.015	65.705	-0.657	1.000
MD+2 vs MD+3	0.004	0.015	325.379	0.260	1.000
MD+2 vs MD+5	$6.674 \times 10^{-4}$	0.015	147.511	0.044	1.000
MD+3 vs MD+5	-0.003	0.015	184.393	-0.220	1.000

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed a significant main effect of Match Day ( $F(3, 81.89) = 0.197, p = .898$ ).

*Table 1i.* Pairwise contrasts between match days derived from the linear mixed model for the KTWi-L female

	Estimate	SE	df	t	p†
MD vs MD + 2	-0.018	0.020	18.431	-0.874	1.000
MD vs MD+3	-0.001	0.016	54.974	-0.067	1.000
MD vs MD+5	-0.005	0.017	27.338	-0.275	1.000
MD+2 vs MD+3	0.017	0.018	37.533	0.935	1.000
MD+2 vs MD+5	0.013	0.016	57.631	0.798	1.000
MD+3 vs MD+5	-0.004	0.015	151.047	-0.234	1.000

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed a significant main effect of Match Day ( $F(3, 45.66) = 0.344, p = .794$ ).

In the male group, most objective measures remained relatively stable across the analysed time points. No clear time-related changes were observed for the ASTi,

SRTi, or KTWi-R (Table 2f-2h). A significant effect of time point was detected only for the KTWi-L ( $F(3, 31.39) = 3.93, p = .017$ ), with a difference observed between MD+3 and MD+5 ( $p = .015$ ) (Table 2i).

*Table 2f.* Pairwise contrasts between match days derived from the linear mixed model for the ASTi male

	Estimate	SE	df	t	p†
MD vs MD + 2	0.002	0.028	17.992	0.076	1.000
MD vs MD+3	0.003	0.029	18.189	0.097	1.000
MD vs MD+5	0.028	0.023	18.679	1.241	.919
MD+2 vs MD+3	$7.427 \times 10^{-4}$	0.013	106.967	0.057	1.000
MD+2 vs MD+5	0.026	0.014	39.054	1.850	.431
MD+3 vs MD+5	0.025	0.015	22.716	1.741	.476

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed a significant main effect of Match Day ( $F(3, 39.44) = 2.18, p = .105$ ).

*Table 2g.* Pairwise contrasts between match days derived from the linear mixed model for the SRTi male

	Estimate	SE	df	t	p†
MD vs MD + 2	-0.019	0.012	33.606	-1.623	.456
MD vs MD + 3	-0.026	0.011	4.057	-2.271	.424
MD vs MD + 5	-0.025	0.012	10.285	-2.120	.356
MD + 2 vs MD + 3	-0.006	0.012	16.044	-0.526	1.000
MD + 2 vs MD + 5	-0.006	0.012	69.943	-0.511	1.000
MD + 3 vs MD + 5	$4.524 \times 10^{-4}$	0.012	7.319	0.036	1.000

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed a significant main effect of Match Day ( $F(3, 12.27) = 2.28, p = .131$ ).

*Table 2h.* Pairwise contrasts between match days derived from the linear mixed model for the KTWi-R male

	Estimate	SE	df	t	p†
MD vs MD + 2	$9.408 \times 10^{-4}$	0.014	164.897	0.069	1.000
MD vs MD+ 3	-0.024	0.013	53.960	-1.801	.367

Table 2h. (continued)

	Estimate	SE	df	t	p†
MD vs MD + 5	0.004	0.013	108.410	0.293	1.000
MD + 2 vs MD + 3	-0.025	0.014	88.282	-1.811	.367
MD + 2 vs MD + 5	0.003	0.014	53.045	0.200	1.000
MD + 3 vs MD + 5	0.027	0.013	17.706	2.107	.298

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed no significant main effect of Match Day ( $F(3, 45.76) = 1.85, p = .151$ ).

Table 2i. Pairwise contrasts between match days derived from the linear mixed model for the KTWiL male

	Estimate	SE	df	t	p†
MD vs MD+2	-0.007	0.016	20.345	-0.435	.668
MD vs MD+3	-0.025	0.016	19.424	-1.547	.434
MD vs MD+5	0.025	0.015	24.594	1.665	.434
MD+2 vs MD+3	-0.017	0.015	43.615	-1.165	.501
MD+2 vs MD+5	0.032	0.014	117.796	2.351	.102
MD+3 vs MD+5	0.050	0.015	30.630	3.305	.015

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary of the linear mixed-effects model showed a significant main effect of Match Day ( $F(3, 31.39) = 3.93, p = .017$ ).

A concise overview of the main patterns observed across objective readiness variables is provided in the summary Table 3.

### Comparison Between Males and Females

Sex-related differences in subjective and objective readiness variables were analysed using linear mixed-effects models with athletes included as a random effect. A first comparison has been made using the 4-dRi to see the different patterns of load management of dRIs over time. The analysis revealed a significant Sex  $\times$  Time point interaction ( $F(3, 56.27) = 4.66, p = .006$ ). Pairwise comparisons indicated a significant difference between females and males at MD ( $p = .031$ ), whereas no

differences were observed at the subsequent time points (Table 3a).

Secondly, to assess objective readiness, a comparison using the three field-test indexes has been conducted to determine whether there are discrepancies between the two groups' scores. A similar pattern was observed for ASTi, with a significant Sex  $\times$  Time point interaction ( $F(3, 104.20) = 3.23, p = .025$ ). Post-hoc comparisons showed a significant difference between sexes at MD+3 ( $p = .031$ ), while no differences were found at the other time points (Table 3b). On the contrary, SRTi, KTWi-R, and KTWi-L showed no significant sex differences, and no significant Sex  $\times$  Time-point interactions were detected (Table 3c-3e).

Table 3a. Pairwise contrasts between female and male groups at each time point relative to match day derived from the linear mixed-effects model for the 4-dRi

	Estimate	SE	df	t	p†
MD(F) vs MD(M)	-0.059	0.021	43.543	-2.798	.031
MD+2(F) vs MD+2(M)	-0.005	0.027	41.540	-0.173	1.000
MD+3(F) vs MD+3(M)	-0.009	0.025	39.829	-0.382	1.000
MD+5(F) vs MD+5(M)	0.027	0.025	40.611	1.056	.892

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary showed no significant main effect of Sex ( $F(1, 42.57) = 0.35, p = .560$ ), a significant effect of time point ( $F(3, 56.27) = 6.13, p = .001$ ), and a significant Sex \* time point interaction ( $F(3, 56.27) = 4.66, p = .006$ ).

**Table 3b.** Pairwise contrasts between female and male groups at each time point relative to match day derived from the linear mixed-effects model for the ASTi

	Estimate	SE	df	t	p†
MD(F) vs MD(M)	0.048	0.021	47.183	2.329	.073
MD+2(F) vs MD+2(M)	0.002	0.021	40.681	0.078	.938
MD+3(F) vs MD+3(M)	0.057	0.020	44.006	2.785	.031
MD+5(F) vs MD+5(M)	0.033	0.022	46.303	1.538	.262

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary showed a significant main effect of Sex ( $F(1, 45.62) = 4.70, p = .036$ ), no significant main effect of time point ( $F(3, 104.20) = 2.65, p = .053$ ), and a significant Sex \* Time point interaction ( $F(3, 104.20) = 3.23, p = .025$ ).

**Table 3c.** Pairwise contrasts between female and male groups at each time point relative to match day derived from the linear mixed-effects model for the SRTi

	Estimate	SE	df	t	p†
MD(F) vs MD(M)	0.046	0.037	47.492	1.238	.888
MD+2(F) vs MD+2(M)	0.014	0.035	46.318	0.394	1.000
MD+3(F) vs MD+3(M)	0.024	0.035	47.442	0.684	1.000
MD+5(F) vs MD+5(M)	0.021	0.033	43.187	0.644	1.000

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary showed no significant main effect of Sex ( $F(1, 46.90) = 0.60, p = .443$ ), no significant main effect of time point ( $F(3, 113.67) = 1.80, p = .150$ ), and no significant Sex \* Time point interaction ( $F(3, 113.67) = 1.83, p = .145$ ).

**Table 3d.** Pairwise contrasts between female and male groups at each time point relative to match day derived from the linear mixed-effects model for the KTWi-R

	Estimate	SE	df	t	p†
MD(F) vs MD(M)	-0.018	0.030	46.432	-0.586	1.000
MD+2(F) vs MD+2(M)	-0.014	0.030	45.251	-0.472	1.000
MD+3(F) vs MD+3(M)	-0.009	0.031	45.663	-0.299	1.000
MD+5(F) vs MD+5(M)	-0.040	0.029	46.866	-1.375	.702

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary showed no significant main effect of Sex ( $F(1, 46.12) = 0.53, p = .470$ ), no significant main effect of time point ( $F(3, 627.64) = 1.84, p = .139$ ), and no significant Sex \* Time point interaction ( $F(3, 627.64) = 1.06, p = .365$ ).

**Table 3e.** Pairwise contrasts between female and male groups at each time point relative to match day derived from the linear mixed-effects model for the KTWi-L

	Estimate	SE	df	t	p†
MD(F) vs MD(M)	0.005	0.037	45.986	0.145	1.000
MD+2(F) vs MD+2(M)	0.010	0.035	43.036	0.284	1.000
MD+3(F) vs MD+3(M)	0.033	0.038	45.245	0.885	1.000
MD+5(F) vs MD+5(M)	-0.017	0.035	47.402	-0.490	1.000

Note: † P-values are adjusted using Holm adjustment.

The ANOVA summary showed no significant main effect of Sex ( $F(1, 46.45) = 0.06, p = .814$ ), a significant effect of time point ( $F(3, 81.34) = 2.81, p = .045$ ), and no significant Sex \* Time point interaction ( $F(3, 81.34) = 2.24, p = .090$ ).

An overview of the main patterns observed in the comparison between the female and male groups is provided in Table 4.

*Table 4.* Summary of the main patterns observed in the comparison between female and male groups across time points relative to match day (MD, MD+2, MD+3, MD+5)

Variable	Main finding (Female vs Male)
4-dRi	Difference between sexes at MD
ASTi	Difference between sexes at MD+3
SRTi	No sex differences
KTWi-R	No sex differences
KTWi-L	No sex differences

## Discussion

### Subjective Readiness Monitoring

The results obtained for the male group show that 4-dRi monitoring followed a trend that may be related to the players' physical and mental fatigue (Drole et al., 2025). In fact, the significant differences highlighted for FWi between MD and the other days can be explained by the fact that on match day, players feel the game and experience less fatigue and anxiety, thereby increasing their overall sense of readiness. As for DOMSi, having a higher value on MD means that players are in the right physical condition to face a match because they have recovered enough from the weekly load. Moreover, in line with the monitoring framework proposed in this study, the estimated marginal means for the male group showed a reduction of approximately 20% in 4-dRi at MD+2 relative to the players' personal best values, as reported in Table S2. This decrease may indicate that athletes are approaching the red zone, a phase of reduced readiness that occurs around 48h after match exposure and reflects the transient fatigue accumulated during competition.

In the female group, 4-dRi showed no clear relationship with the analysed time points, suggesting that readiness status in female athletes may be influenced by additional factors, particularly the menstrual cycle. Therefore, depending on the phase the athlete is in, she may be affected differently by the hormonal fluctuations typical of the menstrual cycle, especially

oestrogens and progesterone, which are most responsible for the different psychological and physical sensations that occur on different days of the cycle (O'Brien, 2011) in women. Lower index values were observed 48h post-match (MD+2), followed by a subsequent increase at 72h post-match (MD+3). As shown in Table 1f, ASTi values decreased from MD to MD+2 and then increased from MD+2 to MD+3, suggesting that this test may be a useful indicator for monitoring post-match recovery in female athletes, indicating they may still be fatigued from the competition.

Men seemed unaffected by fatigue. Either their recovery was faster post-match, or the values over time remained fairly regular because of a hypothetical influence of the "Learning Effect" (Lund et al., 2005)—which is the process whereby repeating a new motor skill within short periods of time leads to rapid improvements in performance, which become smaller and smaller as one becomes more familiar with the action.

### Comparison Between Males and Females

Between the two research groups, the analysis of 4-dRi revealed that subjective readiness perception differs by sex. On match days (MD), the days when players should feel at their best to face the game, there was a difference. Men showed their highest index as expected (Figure S2e). Women, on the other hand, had a lower value index that did not reach their maximum score, with a higher estimated

marginal mean observed at MD+3 (Figure S1e), likely because they experienced greater stress and performance anxiety on match day, leading to a lower sense of general readiness.

After MD, the male values settled at a lower index and remained constant (Figure S2e). While in females, there were fluctuations between lower and higher values that were difficult to associate with a dissimilar management of fatigue and anxiety; the values would all have to be higher than MD, or even MD+5 would have shown high values as MD+3 did (Figure S1e). These intergroup differences are more likely to be related to the menstrual cycle in women, making it more difficult to assess whether the decrease in readiness is linked to performance- or hormonal-related factors (Roffler et al., 2024).

Regarding RDs, the comparison between the two groups revealed discrepancies only for ASTi, where men resulted in having lower values than their female counterparts, especially on MD+3 (Figure S3b), where lower estimated marginal means were observed; and on MD, where the value increased, but it remained significantly different from the female one. However, on MD+2 they almost had the same index, and on MD+5 it was only slightly divergent.

The general trend among females followed the expected pattern: a higher estimated marginal mean on MD, then the lowest index values on MD+2, which increased again on MD+3 and MD+5. Males did not seem to follow the same trend, showing index values that decreased during the week, then increased on MD and MD+2. These differences in the pattern after a match may reflect distinct fatigue states, as recovery is not the same for all athletes; it depends heavily on the minutes played, the position played, and the number of collisions.

In this context, the aggregated readiness index (4-dRi) in the male group appeared to provide a clear reference for identifying the “red zone”, as the decrease

observed at MD+2 (48h post-match) corresponded to the hypothesised phase of reduced readiness.

Finally, comparing SRTi, KTWi, both for the right limb (KTWi-R) and the left limb (KTWi-L), there were no significant differences to report. The index values in both groups followed a fairly regular trend during the week, deviating by a maximum of 0.03-0.04 points from MD (Figure S3d-S3e). It can therefore be concluded that these tests were not very suitable for monitoring players' health, as they are highly dependent on each subject's ankle dorsiflexion mobility and hamstring flexibility and therefore vary little unless specifically trained.

### Results in Relation to the Specific Context of the Discipline

As this is one of the few studies conducted on women (Baptista et al., 2025; Roffler et al., 2024), it is not possible to make direct correlations with other studies in the current literature, but only to compare women with their male counterparts. However, by taking the male group exclusively, it is possible to relate them to other male populations on which similar studies have been conducted.

Ramírez-López et al. (2020a; 2020b; 2022) carried out various fatigue monitoring protocols using both questionnaires assessing the athlete's wellbeing and physical field tests to assess their readiness on the match day or training sessions. In all cases, it is clear that monitoring via questionnaires is useful for tracking the athlete's readiness and for determining whether the athlete is in a suitable state to compete or in a critical situation (“red zone”). Physical tests, on the other hand, are seen more as a tool for assessing daily-to-daily physical readiness, but they are not very useful for obtaining data to compare over time due to the Learning Effect created by repeating the action.

Finally, the most recent study (Ramírez-López et al., 2022) stated that there was a positive correlation between the perception of subjective readiness, espe-

cially related to the quantity and quality of sleep, and the athlete's technical and tactical performance, thus demonstrating that this kind of monitoring helps to have greater control over performance, thanks to the continuous check of responses to workloads, as hypothesised in this current research.

### Limitations of the Study

The first major limitation is the small sample analysed, which does not represent the entire team of athletes. The group that performed the tests was larger, but some data were deemed insufficient for various reasons.

Secondly, the research was not conducted over the entire competitive season, but only at two distinct moments during the championship, which were more intense in terms of the number of matches per unit of time. This choice was made because, as this was the first time a monitoring questionnaire had been administered to these teams, we wanted to test the athletes' response to the project. We wanted to avoid asking them to fill it out continuously throughout the season, as this could have caused adverse reactions. It is an additional commitment the athlete is required to maintain, and since they were not used to doing so, some might have found it annoying.

Then, it should be noted that, apart from the Adductor Squeeze Test, which was always checked by the same operator, the other two tests were self-administered because the centimetre scales were fixed in the gym and the athletes measured themselves as they entered, without an operator present to check them. This, therefore, implies less accurate measurements, meaning the results are subject to a higher margin of error.

Finally, for women athletes, no information on menstrual cycle phase or contraceptive status was collected. The consequences of this omission explained the interpretation of 4-dRi results, including the possibility that fluctuations in perceived readiness across time points may reflect

hormonal rather than fatigue-related variation.

### Future Developments

Future investigations in this field should aim to continuously develop tools that are more valid and reliable, quick to administer, and that demonstrate a clear correlation with athletes' performance, serving as tools for readiness monitoring and injury prevention.

Having demonstrated how, in a group of only women, it is essential to consider possible alterations in the questionnaire and test scores, future developments in readiness monitoring should take into account the presence of the menstrual cycle and consider differences due to hormonal factors (Carmichael et al., 2021; Legerlotz & Nobis, 2022). For example, a question could be included in the subjective assessment of the questionnaire, asking which phase of the menstrual cycle the athlete is currently in, to build a general picture of her hormonal state and understand the potential consequences for her mood and physical performance.

### Conclusion

In conclusion, the most important result emerging from this study is the sex differences in the utility of dRIs and RDs for readiness monitoring. In women, the results did not indicate significant differences in the subjective assessment, suggesting that this type of monitoring may not be suitable for assessing the perceived readiness of a group of female athletes, possibly due to the influence of the menstrual cycle. While in males it seemed to follow the expected pattern, where the athlete was still in a state of fatigue 48h after the match (MD+2), corresponding to the "red zone," while during the week (MD+3, MD+5), as the next match approaches, the value rose again until it reached its maximum on MD.

The RDs tests chosen, in both cases, revealed not to be very effective in readiness monitoring, apart from a small,

significant effect observed within the women's team. Nevertheless, field tests remain an optimal tool for monitoring daily readiness from a preventive perspective, because any decline in ROM and strength relative to the average immediately indicates the athlete's current status and allows the training load to be adjusted accordingly to avoid potential injury.

Despite this evidence, monitoring perceived readiness is a popular, cost-effective strategy and is often used to select athletes for matches and plan daily training sessions.

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The authors declare no conflicts of interest.

### Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this manuscript, the authors declare that no AI and AI-assisted technologies were used.

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### Notes on Contributors

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*Laura Barachetti* is a former master's student in Sport Science at the University of Milan, who contributed to this research project, which was also the focus of her final thesis. She was both a player and the assistant strength and conditioning coach for the monitored women's team.

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## Supplementary materials

Table S1. Female Group Descriptive Statistics

		Median	Mean	Std. Deviation	IQR	Minimum	Maximum
FWi	MD	0.750	0.739	0.187	0.200	0.200	1.000
FWi	MD+2	0.750	0.720	0.201	0.300	0.250	1.000
FWi	MD+3	0.750	0.730	0.194	0.300	0.250	1.000
FWi	MD+5	0.750	0.697	0.211	0.300	0.250	1.000
SQi	MD	0.800	0.796	0.197	0.250	0.200	1.000
SQi	MD+2	0.800	0.828	0.182	0.250	0.200	1.000
SQi	MD+3	0.800	0.840	0.180	0.250	0.200	1.000
SQi	MD+5	0.800	0.796	0.189	0.325	0.400	1.000
Moi	MD	0.750	0.732	0.182	0.200	0.400	1.000
Moi	MD+2	0.750	0.702	0.186	0.200	0.200	1.000
Moi	MD+3	0.750	0.741	0.211	0.400	0.200	1.000
Moi	MD+5	0.750	0.712	0.182	0.200	0.200	1.000
DOMSi	MD	0.750	0.818	0.168	0.250	0.330	1.000
DOMSi	MD+2	0.750	0.787	0.199	0.250	0.200	1.000
DOMSi	MD+3	0.750	0.809	0.167	0.250	0.500	1.000
DOMSi	MD+5	0.750	0.772	0.192	0.250	0.200	1.000
4-dRi	MD	0.810	0.816	0.121	0.193	0.530	1.000
4-dRi	MD+2	0.820	0.802	0.133	0.135	0.410	1.000
4-dRi	MD+3	0.820	0.826	0.122	0.180	0.410	1.000
4-dRi	MD+5	0.800	0.787	0.134	0.190	0.500	1.000
ASTi	MD	0.890	0.894	0.079	0.100	0.620	1.000
ASTi	MD+2	0.850	0.847	0.096	0.120	0.530	1.000
ASTi	MD+3	0.880	0.878	0.083	0.110	0.670	1.000
ASTi	MD+5	0.880	0.875	0.081	0.110	0.640	1.000
SRTi	MD	0.915	0.884	0.134	0.080	0.330	1.000
SRTi	MD+2	0.910	0.871	0.139	0.130	0.320	1.020
SRTi	MD+3	0.920	0.887	0.136	0.100	0.290	1.000
SRTi	MD+5	0.920	0.885	0.134	0.075	0.290	1.000
KTWi-R	MD	0.820	0.801	0.137	0.203	0.430	1.000
KTWi-R	MD+2	0.840	0.811	0.142	0.180	0.420	1.000
KTWi-R	MD+3	0.830	0.816	0.126	0.155	0.430	1.000
KTWi-R	MD+5	0.810	0.814	0.125	0.150	0.430	1.000
KTWi-L	MD	0.860	0.809	0.167	0.268	0.360	1.000
KTWi-L	MD+2	0.870	0.829	0.135	0.160	0.450	1.000
KTWi-L	MD+3	0.870	0.827	0.143	0.205	0.400	1.000
KTWi-L	MD+5	0.860	0.821	0.126	0.150	0.450	1.000

*Figure S1.* Distribution of subjective and objective measures in the Female Group across match day (MD) and the three subsequent days (MD+2, MD+3, and MD+5). Each panel displays a different variable. Black horizontal lines represent estimated marginal means derived from the linear mixed-effects model.

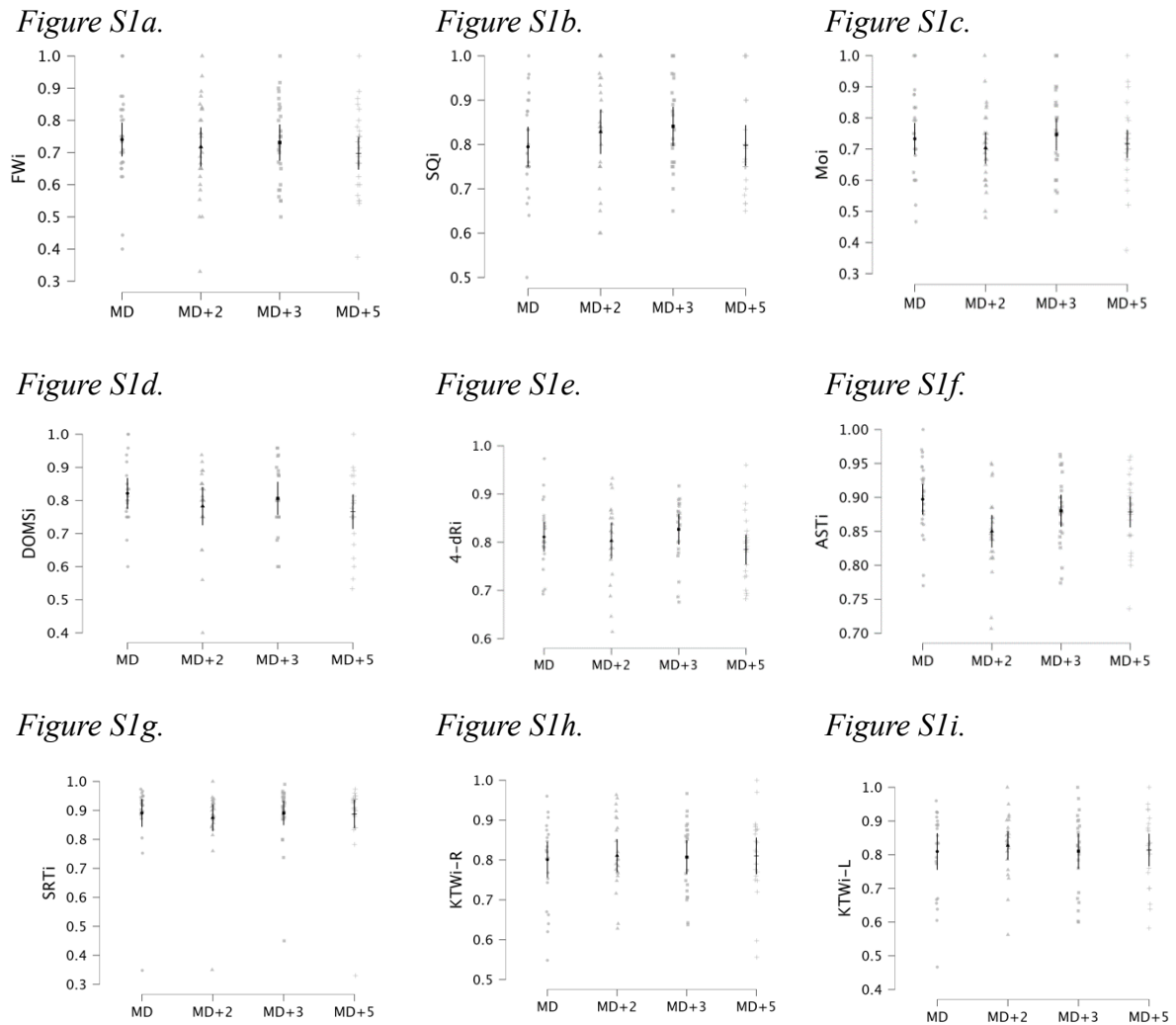


Table S2. Male Group Descriptive Statistics

		Median	Mean	Std. Deviation	IQR	Minimum	Maximum
FWi	MD	0.750	0.835	0.176	0.250	0.250	1.000
FWi	MD+2	0.750	0.717	0.185	0.250	0.330	1.000
FWi	MD+3	0.750	0.695	0.179	0.250	0.250	1.000
FWi	MD+5	0.750	0.719	0.205	0.275	0.200	1.000
SQi	MD	1.000	0.877	0.166	0.200	0.200	1.000
SQi	MD+2	0.800	0.826	0.162	0.250	0.400	1.000
SQi	MD+3	0.800	0.805	0.172	0.250	0.200	1.000
SQi	MD+5	0.800	0.854	0.160	0.250	0.400	1.000
Moi	MD	1.000	0.813	0.234	0.250	0.200	1.000
Moi	MD+2	0.750	0.751	0.227	0.400	0.200	1.000
Moi	MD+3	0.750	0.759	0.234	0.400	0.200	1.000
Moi	MD+5	0.800	0.795	0.218	0.400	0.200	1.000
DOMSi	MD	0.800	0.861	0.147	0.250	0.500	1.000
DOMSi	MD+2	0.750	0.805	0.168	0.250	0.200	1.000
DOMSi	MD+3	0.750	0.782	0.163	0.250	0.200	1.000
DOMSi	MD+5	0.750	0.714	0.190	0.175	0.200	1.000
4-dRi	MD	0.880	0.871	0.110	0.140	0.530	1.000
4-dRi	MD+2	0.820	0.801	0.123	0.170	0.530	1.000
4-dRi	MD+3	0.800	0.792	0.118	0.170	0.440	1.000
4-dRi	MD+5	0.800	0.795	0.114	0.150	0.470	1.000
ASTi	MD	0.880	0.851	0.108	0.120	0.380	1.000
ASTi	MD+2	0.880	0.855	0.099	0.120	0.480	1.000
ASTi	MD+3	0.880	0.846	0.110	0.120	0.440	1.000
ASTi	MD+5	0.850	0.825	0.112	0.120	0.380	1.000
SRTi	MD	0.880	0.846	0.148	0.140	0.270	1.000
SRTi	MD+2	0.900	0.872	0.119	0.140	0.380	1.000
SRTi	MD+3	0.900	0.881	0.108	0.120	0.310	1.000
SRTi	MD+5	0.910	0.875	0.132	0.125	0.230	1.000
KTWi-R	MD	0.820	0.812	0.125	0.160	0.450	1.000
KTWi-R	MD+2	0.850	0.831	0.124	0.185	0.450	1.000
KTWi-R	MD+3	0.870	0.842	0.132	0.120	0.360	1.000
KTWi-R	MD+5	0.820	0.815	0.132	0.180	0.270	1.000
KTWi-L	MD	0.830	0.804	0.156	0.180	0.330	1.000
KTWi-L	MD+2	0.900	0.848	0.146	0.165	0.330	1.000
KTWi-L	MD+3	0.900	0.840	0.144	0.170	0.500	1.000
KTWi-L	MD+5	0.800	0.805	0.152	0.160	0.330	1.000

Figure S2. Distribution of subjective and objective measures in the Male Group across match day (MD) and the three subsequent days (MD+2, MD+3, and MD+5). Each panel displays a different variable. Black horizontal lines represent estimated marginal means derived from the linear mixed-effects model.

Figure S2a.

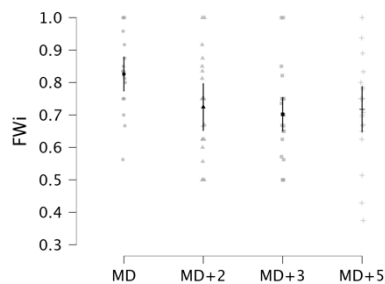


Figure S2b.

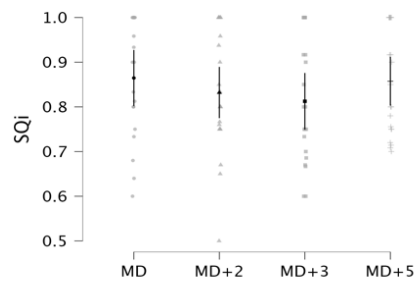


Figure S2c.

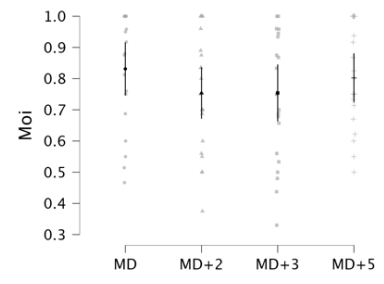


Figure S2d.

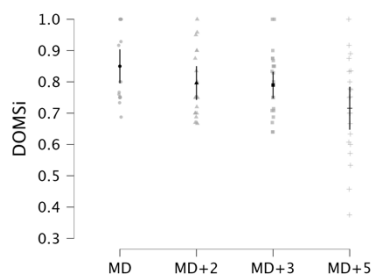


Figure S2e.

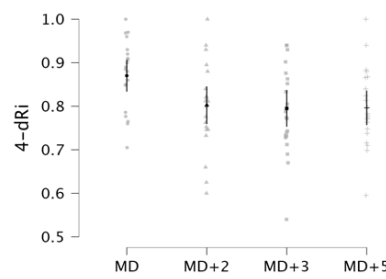


Figure S2f.

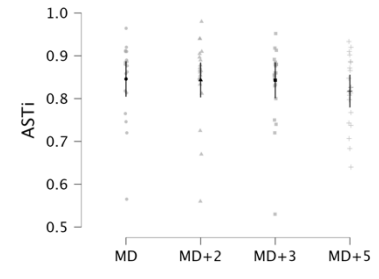


Figure S2g.

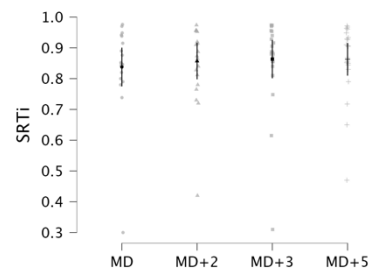


Figure S2h.

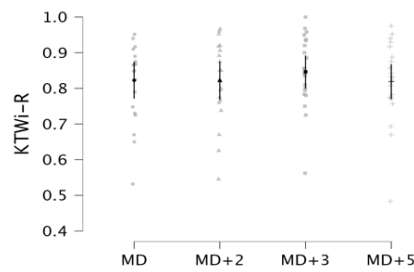


Figure S2i.

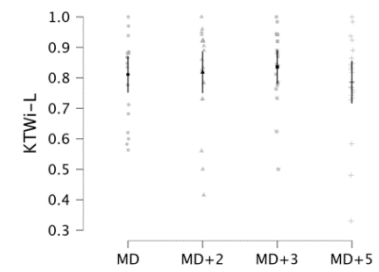


Figure S3. Comparison of the distribution of subjective and objective measures in Female and Male Groups across time points relative to match day (MD, MD+2, MD+3, and MD+5). Black horizontal lines represent estimated marginal means derived from the linear mixed-effects model.

Figure S3a.

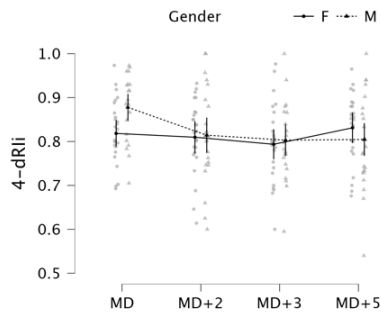


Figure S3b.

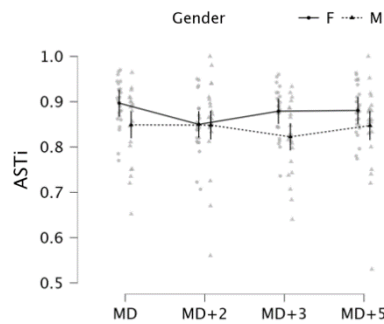


Figure S3c.

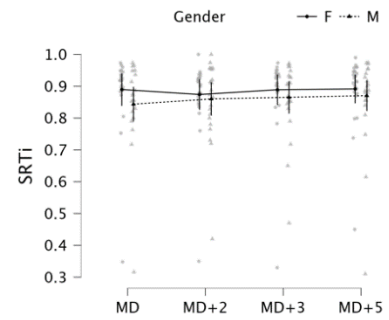


Figure S3d.

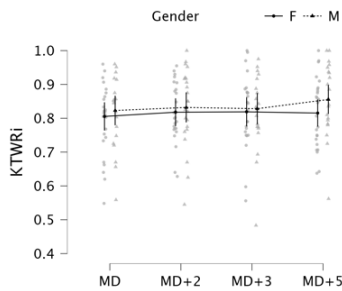


Figure S3e.

