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The effects of menstrual cycle phase on physical performance in female rugby athletes: A case-study

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ABSTRACT

Limited research exists on the effects of menstrual phase on athletic performance in team sport athletes. In this case-study we investigated the potential effect of menstrual cycle phase on several physical qualities in rugby athletes. Four eumenorrhoeic female rugby athletes completed a battery of physical tests weekly for 5-9 weeks, including 10-m sprint, countermovement (CMJ) and drop (DJ) jumps, isometric mid-thigh pull (IMTP), and Bronco. Concurrently, athletes tracked their menstrual cycle with a smartphone application (FitrWoman™). To investigate differences in physical performance between phases, data were allocated into four different menstrual phases at the date of each weekly test. A mixed linear model was created for each physical quality of interest. Mean changes between phases were estimated using magnitude-based inferences with 90% confidence intervals. Individual differences between the average score for each menstrual phase with the value predicted by the trend of the other three phases were also assessed. At a group-level, possible greater performances were observed in the CMJ during the late luteal phase compared with menstruation, in the DJ during late luteal compared with luteal, and in the IMTP during late luteal compared with follicular to ovulation (Δ% = 4.9-7.0%). A variety of responses were observed between individuals for all the tests conducted. Understanding and accounting for individual responses during the menstrual cycle will likely be beneficial to training prescription and interpreting performance monitoring results.

1. Introduction

It is well known that the physiology of women is unique and largely influenced by the menstrual cycle (Mujika & Taipale, 2019). The menstrual cycle is a biological rhythm characterised by the cyclic fluctuations of endogenous sex hormones, such as oestrogen and progesterone. A typical menstrual cycle lasts 28–32 days and consists of a follicular phase (~12–14 days; low to rising levels of oestrogens and low levels of progesterone), ovulation (~1 day, preceded by an oestrogen surge) and a luteal phase (~12–14 days; high levels of oestrogens and progesterone) (Sims & Heather, 2018).

While the primary function of oestrogen and progesterone is to support reproduction, the changing concentrations of these hormones across the menstrual cycle have also been found to affect a number of physiological systems, which in turn could have implications on sport performance (Constantini et al., 2005; de Jonge, 2003). However, research findings on this topic are conflicting, with large variance between studies. These equivocal findings are likely attributable to differences in study design, participants' characteristics, number and definition of menstrual cycle phases, phase verification methods, variables measured, and relatively small sample sizes (de Jonge et al., 2019; Julian et al., 2017; McNulty et al., 2020).

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A limited number of studies have investigated the effects of menstrual cycle phase on physical performance in team sport athletes, with most of the research addressing individual sport athletes or untrained people. Previous studies conducted in female soccer athletes revealed unclear and non-significant differences in sprint, repeated sprint ability, and jumping performance between phases (Julian et al., 2017; Somboonwong et al., 2015; Tounsi et al., 2018); however, while Tounsi et al. (2018) observed no differences in the Yo-Yo Intermittent Recovery Test Level 1 between early follicular, late follicular, and luteal phases, Julian et al. (2017) reported possibly better performance in the Yo-Yo Intermittent Recovery Test Level 2 during the early follicular phase compared to mid luteal (effect size, ES = 0.56). The different aerobic and anaerobic contributions to the two tests (Bangsbo et al., 2008) might explain the contrasting results.

Rugby is a high-intensity, intermittent, field-based contact sport that requires players to possess a range of physical qualities, including speed, power, strength, and fitness (Ross et al., 2014). To date, only one study (Miskec et al., 1997) has evaluated the potential influence of menstrual cycle phases in rugby athletes. Specifically, these results highlighted no significant differences between early follicular and luteal phase on anaerobic power output during repeated high-intensity, intermittent exercise on a cycle ergometer. However, no further physical tests were conducted. There is a requirement for more ecologically valid research in this area, and specifically data that are relevant at an individual level. In support of this statement, a recent study addressing elite female rugby athletes has highlighted the importance to develop understanding on the menstrual cycle and considering its impact on training and competition on female rugby athletes (Findlay et al., 2020). Therefore, in this case-study we investigated the potential effect of menstrual cycle phase on several physical qualities in female rugby athletes. Due to the variability observed in the concentration of sex hormones and timing of cycle phases both between- and within-subjects (Haggstrom, 2014; Vescovi, 2011), participants' individual responses to cycle phases were assessed, in addition to average group responses.

2. Methods

2.1. Participants

Eighteen non-elite female rugby athletes (mean ± standard deviation: age, 23 ± 3 years; height, 1.67 ± 0.05 m; body mass, 80 ± 18 kg) from the same New Zealand Provincial Union were recruited to participate. Four athletes fulfilled all inclusion criteria (age, 23 ± 4 years; height, 1.69 ± 0.05 m; body mass, 67 ± 6 kg; menstrual cycle duration, 30 ± 4 days) and were included in the analysis (Figure 1). Inclusion criteria for participation were: being injury free, the absence from any form of contraception for at least six months, having a menstrual cycle duration of 24-35 days before the beginning of the study (Lebrun et al., 1995), and completing at least one testing session in each of the four menstrual cycle phases considered. Written informed consent was obtained from each participant and approval was obtained from the University of Waikato Human Research Ethics Committee (HREC#2018-10).

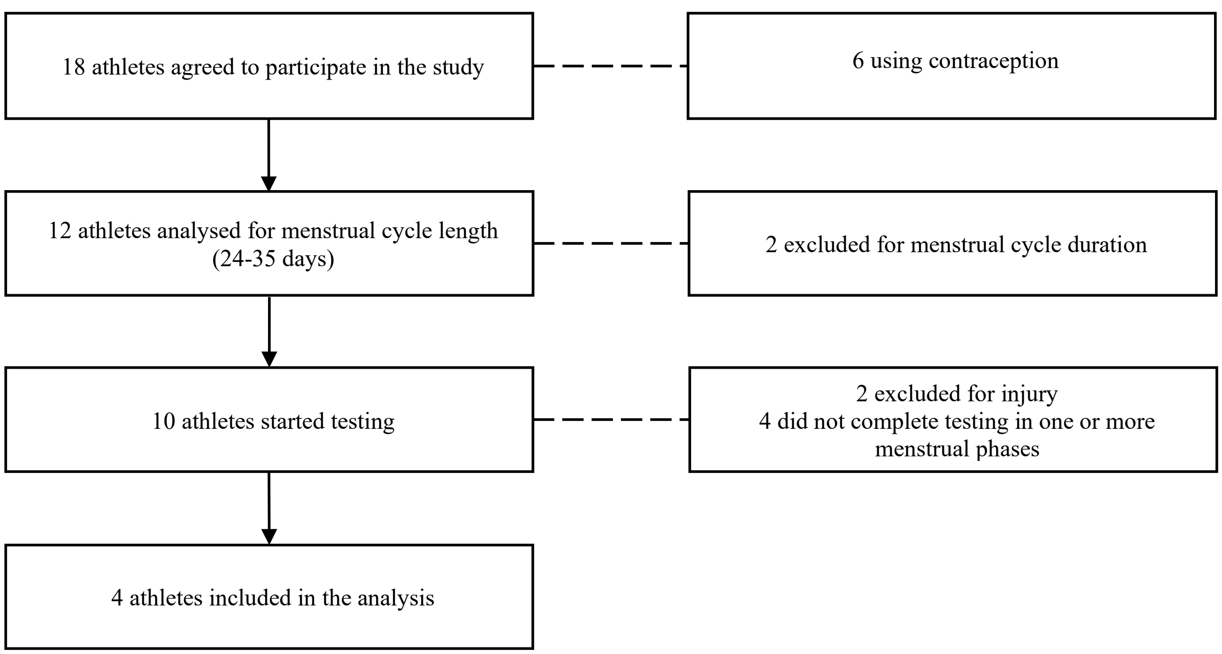

Figure 1: Participant flow chart

2.2. Study design

An observational study design with repeated measures was used. Participants completed a battery of physical tests weekly, for 5-9 consecutive weeks, during the preparation period. Concurrently, they tracked their menstrual cycle daily for the duration of the study.

Physical testing was performed weekly, irrespective of the menstrual phase for a given individual. Participants' data were de-identified to the principal investigators to maintain blinding of the menstrual cycle phase at the time of testing.

A familiarisation session was completed for all testing procedures before the start of the study. The physical assessments were conducted in the same order, on the same day of the week, at the same time of the day (Taylor et al., 2010; Teo et al., 2011) for the duration of the study. Participants were asked to standardise their dietary intake and to abstain from alcohol within the 24 hours before each test.

2.3. Physical tests

A 10-minute standardised warm up comprising of dynamic stretches, jogging, running drills, and stride outs was performed before starting the physical testing.

Acceleration. Acceleration abilities were assessed using a 10 m sprint with split times at 5 and 10 m. The test was completed indoor in running shoes using single beam timing lights (Brower Timing System, Utah, USA). The first gate was set at 0.5 m, while the remaining were set at a height of 0.75 m. Sprint times at each split were measured to the nearest 0.01 second. Participants started each sprint in a standing split position 0.5 m behind the first gate and were instructed to "run as fast as possible" past the last gate. Each participant was given one warm-up trial followed by three maximal sprints, separated by two min of rest. The repeatability for 10-m sprint times conducted under similar conditions is excellent (intraclass correlation coefficient, ICC = 0.90) (Goodale et al., 2016).

Lower-body power. Body weight countermovement jump (CMJ) and drop jump (DJ) were assessed using an optical measurement system (OptoJump Next, Microgate, Bolzano, Italy) sampling at 1000 Hz. For the CMJ, participants started from an upright standing position with their hands-on hips. Participants were instructed to "bend their knees to a self-selected depth and to jump as high as possible". For the DJ, participants stepped out and dropped off a 30 cm high box keeping their hands on their hips. Participants were instructed to "minimise time spent in contact with the ground and jump as high as possible as quickly as possible". For both jumps, one warm-up trial was given, followed by three maximal jumps separated by five seconds. CMJ height estimated from flight time and DJ reactive strength ratio (RSR) defined as the ratio between flight time and contact time were considered for analysis. These variables (CMJ height and RSR) have been shown reliable using similar equipment based on coefficient of variation values (CV = 2.2 and 4.2%, respectively) (Byrne et al., 2017; Glatthorn et al., 2011).

Strength. Maximal strength was measured via the isometric mid-thigh pull exercise (IMTP) using a force measurement system comprising of a strain gauge load cell and software package sampling at 1000 Hz (The Strength Assessment Tool, AUT University, Auckland, NZ). The load cell was anchored to a wooden platform and connected to handles via chains. Testing protocol and position were standardised in agreement with the guidelines of Comfort et al. (e.g., knee angle 125-145°, hip angle 140-150°) (Comfort et al., 2019) and kept consistent for each athlete throughout the study. Participants were instructed to pull "as hard and as fast as possible" for three seconds. Verbal encouragement was given throughout the pull. Two sub-maximal IMTP trials at increasing intensities were given, followed by three maximal efforts interspersed by two minutes of passive rest. Peak force (PF) determined as the maximum force generated during the three seconds pull was recorded and considered for the analysis. PF assessed with a similar device has been found to be reliable (ICC = 0.96 and CV = 3.1%) (James et al., 2017).

Fitness. The 1.2 km shuttle run test, also known as Bronco test (Kelly & Wood, 2013) was used as a measure of fitness. The test was performed outdoors, on the same surface, in running shoes. The protocol consists of a continuous 20, 40, 60 m straight shuttle run, completed five times at maximal intensity (i.e., 20 m and back, 40 m and back, 60 m and back) (Kelly & Wood, 2013). Total running time was recorded and used for analysis. Excellent test-retest reliability of Bronco times has been reported (ICC = 0.99) (Brew & Kelly, 2014).

2.4. Menstrual cycle monitoring

Menstrual cycle information was tracked daily with a smartphone application (FitrWoman™). Participants started the monitoring 10 weeks prior to the start of physical testing to determine their menstrual cycle duration as required by the inclusion criteria. Participants continued to monitor their cycle throughout the 9-week duration of the study.

The length of the menstrual cycle was calculated from the first day of menses to the day preceding the next menses. By inputting typical cycle length, period duration, and the date of their last period, FitrWoman™ estimates menstrual cycle phases. The application divides the menstrual cycle duration in four phases: Phase 1 (menstruation), Phase 2 (follicular to ovulation), Phase 3 (luteal), and Phase 4 (late luteal).

2.5. Training load and well-being

The internal training load for all training sessions completed by each participant during the 5 to 9-week period was calculated using the session-RPE method (Foster et al., 2001). This method quantifies internal training load as the product of the training session rate of perceived exertion (RPE) multiplied by session duration.

The Daily Analysis of Life Demands for Athletes (DALDA) questionnaire (Rushall, 1990) was employed as a measure of well-being. The questionnaire contains 34 items to evaluate the sources and symptoms of stress. Each question can be answered either as "worse than normal", "normal", or "better than normal". Participants filled the questionnaire at each testing session before the warm up.

2.6. Hydration status

To minimise the effects of hypohydration on physical performance outcome (McDermott et al., 2017), the hydration status of every participant was verified on each testing day before the warm up. Urine specific gravity (USG) was measured using urine test strips (Combur®-Test strip, Roche Diagnostics). This method has been shown to be valid and reliable ("Combur-Test® strip", 2020; Warren et al., 2018; Zubac et al., 2014). When the USG value was between 1.020 and 1.025, participants were asked to ingest a 5 ml/kg of body mass beverage (Na^+: 132 mg/100 ml, K^+: 78 mg/100 ml, CHO: 1.4 g/100 ml, mOsm/L: 230 mmol/L). With a USG of 1.030 or higher, 10 ml/kg of body mass of the same beverage was given (Sawka et al., 2007). Furthermore, if the pH value recorded was 7 or more, 0.005 was added to the USG score (Abbey et al., 2014).

2.7. Statistical analysis

At the end of the 9-week period, data were allocated into menstruation, follicular to ovulation, luteal, or late luteal phases at the date of each testing session. Except for the Bronco, the average of the best two scores achieved in the tests at every session was used for analysis.

To investigate differences in physical performance between menstrual phases, physical test scores were log-transformed and analysed using the mixed linear model procedure (Proc Mixed) in the Statistical Analysis System (University Edition of SAS Studio, version 9.4, SAS Institute, Cary NC). A model was created for each physical quality of interest. Menstrual cycle phase, the mean change over the duration of the study, and the weekly training load before each testing session were included in the model as fixed effects. The differences between athletes in the middle of the study and the individual differences in the overall change were entered as random effects with an unstructured covariance matrix to allow these two effects to be correlated.

Mean changes between phases were estimated using magnitude-based inferences with 90% CI (Hopkins, 2006) and are presented as a percent. Furthermore, the effects of training load on the physical tests results were quantified using the same approach. Quantitative chances of higher or lower differences were evaluated qualitatively as follows: <0.5%, most unlikely; 0.5−5%, very unlikely; 5−25%, unlikely; 25−75%, possibly; 75−95%, likely; 95−99.5%, very likely; >99.5%, most likely. If the probabilities of the true value being substantially higher and lower were both >5%, the difference was termed as unclear.

Individual differences between the mean score for each menstrual phase with the mean predicted by the trend of the other three phases were assessed for each physical quality (Hopkins, 2017). Specifically, the residual obtained from the mixed linear model was used as typical error in percent units. The smallest worthwhile change (SWC = 0.2 x between-subjects SD) calculated from previous data collected in our lab was used to establish the smallest important change in percent units. Quantitative chances of higher or lower differences were evaluated qualitatively as follows: <10%, very unlikely; 10−90%, possible; >90%, very likely. If the probabilities of the true value being substantially higher and lower were both >10%, the difference was termed as unclear.

With regards to wellness, DALDA responses were coded as 1 = "worse than normal", 2 = "normal", and 3 = "better than normal" and summed across the 34 items. The total score obtained in the questionnaire by each athlete was then rescaled to range from 0 to 100. Individual differences in the average scores between phases were interpreted as small, moderate, large, very large, and extremely large when reaching thresholds of 10, 30, 50, 70, and 90%, respectively.

3. Results

All data are presented as mean ± SD, unless otherwise indicated. The maximum variation in cycle length throughout the study was five days. Individual average physical performance results specific to menstrual cycle phase and the number of testing sessions completed in every phase by each participant are reported in Table 1.

Mean differences in physical performance between menstrual cycle phases are reported in Table 2. At a group-level, possible lower CMJ performance was observed in the menstruation phase compared to late luteal (Δ% = -4.9%). Possible lower DJ performance was observed in the luteal phase compared to late luteal (Δ% = -7.0%). Furthermore, possible lower IMTP performance was observed in the follicular to ovulation phase compared to late luteal (Δ% = -6.0%). All other phase differences were possible to very likely trivial or unclear.

Individual differences in physical performance are reported in Table 3. One participant had very likely slower 5-m time in the luteal phase compared with the trend of the other three phases. Another athlete displayed possible greater IMTP performance in the menstruation phase compared with the trend of the other three phases. With regards to the Bronco test, one athlete showed very likely trivial differences between the follicular to ovulation phase with the trend of the other three phases, and between the luteal phase with the trend of the other three phases; furthermore, another athlete displayed a possible trivial difference between the late luteal phase with the trend of the other three phases. The remaining comparisons were unclear or were scored both as a possible substantial increase or decrease and a possible trivial difference.

Training load had a possible to very likely trivial effect on Bronco, CMJ, DJ, 5-m, and 10-m speed scores. An unclear effect was registered for the IMTP. Trivial to small differences were observed in well-being (DALDA) between phases at an individual level (Figure 2).

4. Discussion

This is the first study investigating the effects of menstrual cycle phase on several physical qualities in rugby athletes over multiple testing sessions. The inclusion and analysis of participants' individual responses to cycle phase, in addition to the group average responses, also represent a novelty.

Table 1: Individual average physical performance results specific to menstrual cycle phase across 5 to 9 weeks.

Test	Phase[a]	Participants			
		1	2	3	4
5-m time (s)	Phase 1 (*n*)	1.14 ± NA (*1*)	1.08 ± NA (*1*)	1.12 ± NA (*1*)	1.06 ± 0.00 (*2*)
	Phase 2 (*n*)	1.15 ± 0.02 (*4*)	1.08 ± 0.00 (*2*)	1.12 ± 0.03 (*4*)	1.07 ± 0.01 (*2*)
	Phase 3 (*n*)	1.14 ± 0.03 (*3*)	1.07 ± 0.01 (*2*)	1.11 ± 0.03 (*3*)	1.12 ± 0.05 (*2*)
	Phase 4 (*n*)	1.16 ± NA (*1*)	1.07 ± 0.01 (*2*)	1.12 ± NA (*1*)	1.07 ± 0.01 (*2*)
10-m time (s)	Phase 1 (*n*)	1.96 ± NA (*1*)	1.82 ± NA (*1*)	1.95 ± NA (*1*)	1.85 ± 0.01 (*2*)
	Phase 2 (*n*)	1.94 ± 0.01 (*4*)	1.82 ± 0.02 (*2*)	1.93 ± 0.04 (*4*)	1.87 ± 0.01 (*2*)
	Phase 3 (*n*)	1.94 ± 0.04 (*3*)	1.83 ± 0.02 (*2*)	1.92 ± 0.07 (*3*)	1.89 ± 0.05 (*2*)
	Phase 4 (*n*)	1.95 ± NA (*1*)	1.81 ± 0.02 (*2*)	1.93 ± NA (*1*)	1.84 ± 0.01 (*2*)
CMJ height (cm)	Phase 1 (*n*)	34.0 ± NA (*1*)	35.7 ± 5.4 (*2*)	29.7 ± NA (*1*)	35.5 ± 1.9 (*2*)
	Phase 2 (*n*)	34.9 ± 1.7 (*4*)	38.7 ± NA (*1*)	29.2 ± 2.3 (*4*)	35.2 ± 2.6 (*2*)
	Phase 3 (*n*)	33.9 ± 1.2 (*3*)	38.4 ± 0.3 (*2*)	30.0 ± 0.6 (*3*)	33.3 ± 4.5 (*2*)
	Phase 4 (*n*)	36.7 ± NA (*1*)	37.8 ± 0.0 (*2*)	27.9 ± NA (*1*)	36.4 ± 2.9 (*2*)
DJ RSR (ratio)	Phase 1 (*n*)	1.37 ± NA (*1*)	1.65 ± NA (*1*)	1.37 ± NA (*1*)	1.41 ± 0.07 (*2*)
	Phase 2 (*n*)	1.32 ± 0.17 (*3*)	1.55 ± NA (*1*)	1.24 ± 0.14 (*3*)	1.39 ± 0.16 (*2*)
	Phase 3 (*n*)	1.28 ± 0.11 (*3*)	1.70 ± 0.09 (*2*)	1.30 ± 0.08 (*3*)	1.27 ± NA (*1*)
	Phase 4 (*n*)	1.39 ± NA (*1*)	1.69 ± 0.06 (*2*)	1.23 ± NA (*1*)	1.50 ± 0.09 (*2*)
IMTP PF (N)	Phase 1 (*n*)	1702 ± NA (*1*)	1833 ± NA (*1*)	1850 ± NA (*1*)	1750 ± 198 (*2*)
	Phase 2 (*n*)	1588 ± 218 (*3*)	1506 ± 415 (*2*)	1628 ± 106 (*3*)	2091 ± 521 (*2*)
	Phase 3 (*n*)	1630 ± 113 (*3*)	1538 ± 136 (*2*)	1599 ± 123 (*3*)	1949 ± NA (*1*)
	Phase 4 (*n*)	1615 ± NA (*1*)	1748 ± 74 (*2*)	1745 ± NA (*1*)	1772 ± 592 (*2*)
Bronco time (s)	Phase 1 (*n*)	360 ± NA (*1*)	310 ± NA (*1*)	335 ± NA (*1*)	338 ± 21 (*2*)
	Phase 2 (*n*)	353 ± 4 (*4*)	303 ± NA (*1*)	346 ± 13 (*4*)	333 ± 4 (*2*)
	Phase 3 (*n*)	355 ± 5 (*3*)	319 ± NA (*1*)	342 ± 19 (*3*)	338 ± 1 (*2*)
	Phase 4 (*n*)	352 ± NA (*1*)	318 ± 1 (*2*)	339 ± NA (*1*)	331 ± 6 (*2*)

Note: [a] Phase 1, menstruation; Phase 2, follicular to ovulation; Phase 3, luteal; Phase 4, late luteal. Data are presented as mean ± SD.
CMJ, countermovement jump; DJ, drop jump; IMTP, isometric mid-thigh pull; *n,* number of testing sessions completed; NA, not applicable; PF, peak force; RSR, reactive strength ratio.

Table 2: Mean differences between menstrual cycle phases.

Test	Phases[a]	Difference (%)	90% confidence limits		Inference[b]
			Lower	Upper	
5-m time (s)	Ph1 – Ph2	-0.6	-2.5	1.4	6/68/26, Unclear
	Ph1 – Ph3	-0.5	-2.5	1.4	6/68/26, Unclear
	Ph1 – Ph4	0.0	-2.2	2.0	14/70/16, Unclear
	Ph2 – Ph3	0.0	-1.4	1.5	8/85/7, Unclear
	Ph2 – Ph4	0.5	-1.3	2.3	23/72/5, Unclear
	Ph3 – Ph4	0.5	-1.4	2.3	23/71/6, Unclear
10-m time (s)	Ph1 – Ph2	-0.1	-1.6	1.3	5/86/9, Unclear
	Ph1 – Ph3	0.2	-1.4	1.7	11/83/6, Unclear
	Ph1 – Ph4	0.5	-1.1	2.1	19/77/4, Likely ↔
	Ph2 – Ph3	0.3	-0.8	1.4	7/92/1, Likely ↔
	Ph2 – Ph4	0.6	-0.8	2.0	21/78/1, Likely ↔
	Ph3 – Ph4	0.3	-1.2	1.8	14/82/4, Likely ↔
CMJ height (cm)	Ph1 – Ph2	-2.2	-6.3	2.1	1/78/21, Likely ↔
	Ph1 – Ph3	-2.6	-6.7	1.6	0/74/26, Possibly ↔↓
	Ph1 – Ph4	-4.9	-9.2	-0.4	0/39/61, Possibly ↓↔
	Ph2 – Ph3	-0.4	-3.8	3.1	2/94/4, Likely ↔
	Ph2 – Ph4	-2.7	-6.8	1.5	0/72/28, Possibly ↔↓
	Ph3 – Ph4	-2.3	-6.5	2.0	1/76/23, Likely ↔
DJ RSR (ratio)	Ph1 – Ph2	1.5	-6.2	9.6	15/79/6, Unclear
	Ph1 – Ph3	3.0	-4.4	11.0	24/74/2, Possibly ↔
	Ph1 – Ph4	-4.2	-11.6	3.7	2/63/35, Possibly ↔↓
	Ph2 – Ph3	1.5	-4.7	8.1	11/86/3, Likely ↔
	Ph2 – Ph4	-5.6	-12.1	1.4	1/53/46, Possibly ↔↓
	Ph3 – Ph4	-7.0	-13.2	-0.3	0/39/61, Possibly ↓↔
IMTP PF (N)	Ph1 – Ph2	5.1	-4.3	15.5	59/35/6, Unclear
	Ph1 – Ph3	3.0	-6.2	13.0	44/45/11, Unclear
	Ph1 – Ph4	-1.1	-10.5	9.2	20/47/33, Unclear
	Ph2 – Ph3	-2.1	-9.2	5.4	10/55/35, Unclear
	Ph2 – Ph4	-6.0	-13.6	2.4	3/29/68, Possibly ↓↔
	Ph3 – Ph4	-4.0	-11.9	4.7	7/41/52, Unclear
Bronco time (s)	Ph1 – Ph2	0.4	-7.8	9.3	14/74/12, Unclear
	Ph1 – Ph3	0.2	-2.3	2.7	3/95/2, Very likely ↔
	Ph1 – Ph4	-0.4	-3.8	3.1	5/87/8, Likely ↔
	Ph2 – Ph3	-0.2	-5.2	5.0	8/84/8, Unclear
	Ph2 – Ph4	-0.8	-3.1	1.5	1/94/5, Likely ↔
	Ph3 – Ph4	-0.6	-3.1	1.9	1/94/5, Likely ↔

Note: [a] Phase 1 (Ph1), menstruation; Phase 2 (Ph2), follicular to ovulation; Phase 3 (Ph3), luteal; Phase 4 (Ph4), late luteal. [b] Likelihood (%): increase/trivial/decrease. ↔ Trivial; ↓ Substantial decrease. CMJ, countermovement jump; DJ, drop jump: IMTP, isometric mid-thigh pull; PF, peak force; RSR, reactive strength ratio.

Table 3: Individual menstrual cycle phase differences.

Test	Phases[a]	Participants			
		1	2	3	4
		Inference[b]	Inference[b]	Inference[b]	Inference[b]
5-m time (s)	Ph 1 - Trend	20/38/42, Unclear	38/45/17, Unclear	41/42/17, Unclear	7/39/54, Possible ↓↔
	Ph 2 - Trend	12/49/39, Unclear	33/54/14, Unclear	31/51/17, Unclear	39/41/20, Unclear
	Ph 3 - Trend	13/61/26, Unclear	12/60/29, Unclear	13/56/31, Unclear	96/3/0, Very likely ↑
	Ph 4 - Trend	41/43/16, Unclear	12/61/27, Unclear	22/35/43, Unclear	7/35/58, Possible ↓↔
10-m time (s)	Ph 1 - Trend	39/47/14, Unclear	32/54/15, Unclear	52/40/8, Possible ↑↔	13/61/26, Unclear
	Ph 2 - Trend	17/59/24, Unclear	21/65/14, Unclear	20/51/29, Unclear	51/44/5, Possible ↑↔
	Ph 3 - Trend	2/71/27, Possible ↔↓	19/70/11, Unclear	17/62/21, Unclear	69/30/1, Possible ↑↔
	Ph 4 - Trend	26/55/19, Unclear	6/67/27, Possible ↔↓	26/38/37, Unclear	1/32/67, Possible ↓↔
CMJ height (cm)	Ph 1 - Trend	5/37/59, Possible ↓↔	0/28/72, Possible ↓↔	21/60/19, Unclear	15/67/18, Unclear
	Ph 2 - Trend	23/63/14, Unclear	6/36/58, Possible ↓↔	2/83/15, Possible ↔↓	1/36/62, Possible ↓↔
	Ph 3 - Trend	2/52/45, Possible ↔↓	72/28/1, Possible ↑↔	29/62/9, Possible ↔↑	5/56/39, Possible ↔↓
	Ph 4 - Trend	73/26/1, Possible ↑↔	21/66/13, Unclear	19/49/32, Unclear	76/24/0, Possible ↑↔
DJ RSR (ratio)	Ph 1 - Trend	11/41/48, Unclear	32/55/13, Unclear	50/43/7, Possible ↑↔	23/55/22, Unclear
	Ph 2 - Trend	31/61/8, Possible ↔↑	7/44/49, Possible ↓↔	3/70/27, Possible ↔↓	12/52/36, Unclear
	Ph 3 - Trend	3/44/53, Possible ↓↔	20/62/18, Unclear	34/42/23, Unclear	2/23/75, Possible ↓↔
	Ph 4 - Trend	72/26/2, Possible ↑↔	17/74/9, Possible ↔↑	26/44/29, Unclear	85/15/0, Possible ↑↔
IMTP PF (N)	Ph 1 - Trend	44/24/32, Unclear	44/26/30, Unclear	89/8/3, Possible ↑	4/18/79, Possible ↓↔
	Ph 2 - Trend	14/37/50, Unclear	10/17/73, Unclear	13/35/52, Unclear	56/26/19, Unclear
	Ph 3 - Trend	27/37/36, Unclear	32/31/37, Unclear	10/21/68, Unclear	51/26/22, Unclear
	Ph 4 - Trend	42/28/31, Unclear	81/16/3, Possible ↑↔	47/24/29, Unclear	44/27/29, Unclear
Bronco time (s)	Ph 1 - Trend	27/66/7, Possible ↔↑	15/71/14, Unclear	4/53/43, Possible ↔↓	17/79/3, Possible ↔↑
	Ph 2 - Trend	5/94/2, Very likely ↔	5/53/42, Possible ↔↓	27/66/7, Possible ↔↑	3/60/37, Possible ↔↓
	Ph 3 - Trend	5/90/4, Very likely ↔	21/70/9, Possible ↔↑	13/75/12, Unclear	42/56/3, Possible ↔↑
	Ph 4 - Trend	10/72/18, Unclear	5/85/10, Possible ↔	18/53/30, Unclear	5/72/23, Possible ↔↓

Note: [a] Phase 1 (Ph1), menstruation; Phase 2 (Ph2), follicular to ovulation; Phase 3 (Ph3), luteal; Phase 4 (Ph4), late luteal. [b] Likelihood (%): increase/trivial/decrease. ↑ Substantial increase; ↔ Trivial; ↓ Substantial decrease. CMJ, countermovement jump; DJ, drop jump; IMTP, isometric mid-thigh pull; PF, peak force; RSR, reactive strength ratio; Trend, value predicted by the trend of the other three phases.

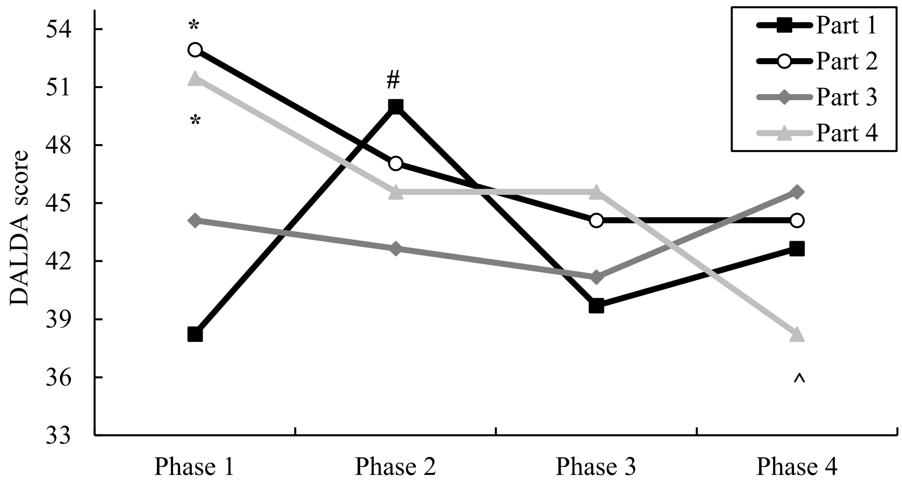

Figure 2: DALDA score specific to each participant. Data are presented as rescaled mean scores for each menstrual cycle phase. Phase 1, menstruation; Phase 2, follicular to ovulation; Phase 3, luteal; Phase 4, late luteal. * = Small difference with Phase 2, Phase 3, and Phase 4. # = Small difference with Phase 1, Phase 3, and Phase 4. ^ = Small difference with Phase 2 and Phase 3.

In female rugby athletes, possibly greater CMJ performance was observed in the late luteal phase compared with the menstruation phase, with possible to likely trivial changes observed between the other phases. Previous research conducted on female soccer athletes reported unclear differences in CMJ height between early follicular and mid luteal phase (Julian et al., 2017). The different study design, menstrual cycle phases considered, and phase verification methods might explain the conflicting results. In the current study, possibly greater DJ performance was observed in the late luteal phase compared with the luteal phase, with the remaining phase comparisons showing possible to likely trivial or unclear differences. No other studies have investigated the effects of menstrual cycle performance on DJ in team sport athletes. However, previous research reported no significant differences in the five-jump test (Tounsi et al., 2018) between the early follicular, late follicular, and luteal phase in female soccer athletes.

Possible greater peak force was observed in the IMTP in the late luteal phase compared with the follicular to ovulation phase in rugby athletes. Unclear differences were observed in other phase comparisons. To the authors' knowledge, no other study has evaluated the influence of menstrual cycle on maximal isometric strength in team sport athletes using multi-joint exercises (i.e., IMTP). A study (dos Santos Andrade et al., 2017) performed on female soccer athletes found the hamstring/quadriceps peak torque strength balance ratio for the non-dominant limb was significantly lower ($p = 0.01$) during follicular phase compared to the luteal phase, which might have implications in terms of lower-limb and anterior cruciate ligament injury risk. In contrast, previous research (Hertel et al., 2006) assessing isokinetic concentric strength in female college students (i.e., soccer and cheerleading) found no substantial fluctuations in hamstring and quadriceps muscle strength across the menstrual cycle at group-level.

Unclear differences were observed across the menstrual cycle in 5-m sprint time in rugby athletes. Furthermore, unclear differences and likely trivial differences were observed between phases in 10-m sprint time. While the trivial differences highlight the absence of a substantial change in performance between phases, the unclear differences are likely attributed to the small sample size employed in this study (Buchheit, 2018). When considering the existing research on team sports, previous studies addressing female soccer athletes showed unclear and non-significant differences between early follicular and mid luteal phases in 5, 10, 30 m sprint times (Julian et al., 2017), and in 40-yard (~37 m) sprint time (Somboonwong et al., 2015). Furthermore, in female soccer athletes, no significant differences were observed between early follicular, late follicular, and luteal phase in a repeated shuttle-sprint ability test (Tounsi et al., 2018).

Likely to very likely trivial or unclear menstrual phase differences characterised the Bronco test. No significant differences in fitness performance were reported between phases in female rugby (Miskec et al., 1997) and soccer athletes (Julian et al., 2017; Tounsi et al., 2018) in previous research. However, in the study of Julian et al. (2017), female soccer athletes covered possibly greater distance in the Yo-Yo Intermittent Recovery Test Level 2 during the early follicular phase compared to mid luteal (ES = 0.56). These findings contrast the results of this study, and may be explained by the different menstrual phases considered and the different tests employed (Sella et al., in press).

To date, most of the research in this area has focused on the average effects of menstrual cycle on physical performance at group-level, without considering and analysing the individual responses. However, it is known that a large inter- and intra-individual variability exist in the concentration of sex hormones and timing of cycle event (Haggstrom, 2014; Vescovi, 2011) that could potentially affect women differently. Therefore, tracking individual performance changes across the different phases of the cycle proves to be critical for athletes and coaches. For example, in this study, no clear differences were observed in 5-m sprint time across the menstrual cycle at group-level. However, one athlete showed very likely slower 5-m time in the luteal phase compared with the trend of the other three phases. These observations suggest impairment in her short acceleration abilities in the luteal phase, which in turn could affect game performance (Clarke et al., 2017). Another athlete displayed possibly greater peak force in the IMTP exercise in the menstruation phase compared with the trend of the other phases, despite no clear differences were observed at group-level between the menstruation phase with the other phases; therefore, further highlighting the need to account for individual performance differences across the menstrual cycle. In collision-based sports such as rugby, high levels of muscular strength are thought to be important to success (Ross et al., 2014); in particular, peak force assessed in the IMTP appears to be associated with performance in numerous athletic tasks in a variety of athletes (Comfort et al., 2019).

It is worth noting that several phase comparisons at group-level and at individual-level, resulted both as a possible substantial increase or decrease and a possible trivial difference. These findings are explained by the magnitude of the SWCs and typical errors (TEs) of the physical tests conducted (TE ~ SWC or TE > SWC), and indicate that the ability to make firm conclusions is limited unless the probability of a substantial change is high. Throughout the study, the weekly training load completed before each testing session did not substantially affect test scores. Trivial to small differences were observed between phases in well-being on the day of testing.

It is important to highlight some limitations of the present study. Firstly, because of the long duration of the investigation, we did not measure oestrogens and progesterone concentrations to verify menstrual cycle phase and no ovulation testing was conducted. Instead, we opted for a designated smartphone application. Compared to direct hormones measurements, this method is a practical, time-efficient and cost-effective alternative to monitor the menstrual cycle (i.e., duration and phase prediction) in a team environment. However, it does not allow distinguishing between ovulatory and anovulatory or luteal phase-deficient cycles, nor does it allow for monitoring the daily variation of hormones between individuals (de Jonge et al., 2019). In addition, knowledge of hormones concentration specific to menstrual cycle phase could have also assisted in explaining performance differences at individual-level between- and within-menstrual cycle phases. Therefore, additional research is required to investigate the validity of this alternative method to monitor menstrual cycle (Julian & Sargent, 2020). While not addressed in the current study, recovery post-exercise may also differ between phases and impact on overall training outcomes.

Out of the participants that were screened for eligibility (n = 18), only 4 completed the study (22%, Figure 1). Large degrees of drop-out rates (75 and 82%) were also observed in previous research conducted in soccer athletes (Julian et al., 2017; Julian et al., 2020), highlighting one of the challenges in conducting this type of research with athletic population in applied settings.

To improve the quality of menstrual cycle research, further studies are required to address the above limitations. In addition, similar to the study of Julian et al. (2020) in soccer, future research is needed to assess the influence of menstrual cycle directly on rugby and other sports' match activities and determinants of success. Lastly, given the high prevalence of contraception in female athletes (Rechichi et al., 2009), the effects of different hormonal profiles should be also considered.

5. Conclusions

In female rugby athletes, possibly greater performances were observed in the CMJ, DJ, and IMTP in the late luteal phase compared with the menstruation, luteal, and follicular to ovulation phases. However, a large variety of responses were observed at an individual-level.

Including menstrual cycle monitoring and understanding the potential effects of cycle phase on physical performance in rugby and other team sports could be of interest for coaches and practitioners. In particular, assessing and accounting for athletes' individual changes during menstrual cycle phases will likely be beneficial for interpreting monitoring results and training prescription.

Conflict of Interest

The authors declare no conflict of interests.

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