The Effects of Menstrual Cycle Phases on Repeated Sprint Ability

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ABSTRACT

Female participation in regular sport activities has increased in recent years, yet their representation in sports and exercise science literature remains low. This can be partly attributed to the complexities associated with the menstrual cycle (MC). Despite these challenges, sport and exercise science studies should not ignore the effects of the MC and its hormonal fluctuations on performance and physiological measures. The aim of this study was to compare performance, physiological and perceptual differences when performing a repeated sprint ability (RSA) exercise during the early-follicular, and mid-luteal sub-phases of the MC. Five healthy, physically active participants (25.4 ± 3.0 years; 1.65 ± 0.1 m; 64.5 ± 18.6 kg; 43.2 ± 5.2 ml $O_2 \cdot kg^{-1}$) took part in this study. The participants completed two familiarization and four intervention sessions (twice during each MC sub-phase) of the RSA exercise. The RSA protocol consisted of five 'all-out' sprints of six seconds on a non-motorized treadmill with 24 seconds of walking between the sprints. Results indicated no significant differences ($p > 0.05$) between MC sub-phases in body mass index, fat mass, mean and peak power output, fatigue index for peak power output, distance, peak acceleration, pre-exercise lactate, oxygen uptake, and heart rate. However, significant differences were found in post-exercise lactate ($p = 0.04$) and rating of perceived exertion ($p = 0.001$). In conclusion, MC phases do not appear to influence most of the chosen RSA performance indicators thus suggesting that practitioners should not tailor repeated sprint exercises based on the MC phases.

Keywords: menstrual cycle, performance, female, ovarian hormones, repeated sprint ability

INTRODUCTION

Previously, most studies in sports and exercise sciences have been conducted on males, with the results generalized to females, without considering how the sex differences may affect the transferability of these results (Bruinvels et al., 2017; Sims & Heather, 2018). In fact, females have been, and still are, often excluded from sport and exercise research, or are often included together with males without giving much consideration to the physiological differences (Johnson et al., 2009). An analysis of 5261 publications from 2014 and 2020 showed that 63% included both males and females, 31% included males only, and 6% included females only, showing a significant underrepresentation of females in sport and exercise sciences (Cowley et al., 2021). Frankovich & Lebrun (2000) and Sims & Heather (2018) indicated that some of the main reasons for the exclusion of females in research studies are the complexities associated with the MC, such as the biphasic response of oestrogen and progesterone, the high variability of hormone fluctuations throughout the day and the differences of hormone concentrations between persons.

The MC is governed by cyclic hormonal fluctuations that follow an established pattern of progesterone, oestrogen, luteinising hormone (LH) and follicle-stimulating hormone (FSH) (Frankovich & Lebrun, 2000). A regular MC lasts between 28 and 32 days, and it can be divided into three phases: follicular (low progesterone and oestrogens), ovulatory and luteal (high progesterone and oestrogens) (Sims & Heather, 2018). Furthermore, the follicular and luteal phases can be divided into sub-phases: early, mid and late (Lebrun et al., 1995).

These hormones have previously been identified to affect female physiology and, in turn, may affect performance (Birch, 2000; Constantini et al., 2005; Draper et al., 2018). For example, oestrogen affects metabolism by reducing gluconeogenesis and glycogenolysis (Bunt, 1990; D'Eon et al., 2002) and increasing fat oxidation, potentially affecting performance that relies on specific metabolic pathways to resynthesise energy (Nicklas et al., 1989). In contrast, progesterone increases muscle glycogen utilisation (D'Eon et al., 2002), and has been recently demonstrated by Mata et al. (2019) to alter carbohydrate availability, thereby affecting performance and training adaptations. This indicates a link between hormonal fluctuations and both physiological and performance changes.

Even though there has been an increased interest in studying the MC and its effects on performance, there is still very limited research on this subject. The current literature shows conflicting and inconclusive results, possibly due to methodological differences such as the definition of MC phases and their verification method, the variables measured and the small sample sizes (Sella et al., 2021).

The effects of the MC on RSA have been studied by Middleton and Wenger (2006) and Graja et al. (2020), which analysed a cycling performance, and by Tounsi et al. (2018) and Ghazel et al. (2022) which analysed a running performance. Middleton and Wenger (2006) analysed 10 sprints of six seconds each with 30 seconds recovery on a cycle ergometer, and reported the average work over a series of sprints and oxygen uptake (VO2) between sprints to be higher during the late-luteal phase than the mid-follicular phase. Graja et al. (2020) analysed 20 sprints of 5 seconds with 25 seconds recovery on a cycle ergometer, and reported a decrease in peak power during the premenstrual phase compared with the late-follicular and mid-luteal phases, and during the mid-luteal phase compared with the late-follicular phase. Furthermore, Graja et al. (2020) reported a lower decrement in peak power during the late-follicular phase than the premenstrual phase, but no differences between the late-follicular and mid-luteal phases. Tounsi et al. (2018) and Ghazel et al. (2022) both analysed 6 sprints of 40 meters with a change of direction of 180° after 20m. Tounsi et al. (2018) reported no significant differences in mean sprint time between the early-follicular, late-follicular and luteal phases. Ghazel et al. (2022) reported no significant differences in mean sprint time, best sprint time and sprint decrement between the early-follicular, mid-follicular and mid-luteal phases.

Even though these 4 studies analyzed the effects of the menstrual cycle on RSA, only Tounsi et al. (2018) and Ghazel et al. (2022) analysed a running performance. However, the protocol chosen is a shuttle sprint, which differs from the protocol chosen in the present study that does not involve any change of direction. The analysis of RSA performance is important because the results could be applied in a multitude of sport activities both in athletes and/ or in general population, where a running modality is common. Repeated sprint ability is considered an important factor for team sports' athletes, as being able to perform several sprints consecutively, with an incomplete rest, is a common situation within these sports (Bishop et al., 2011; Buchheit et al., 2010). Recently, the effectiveness of repeated sprint exercise has also been demonstrated in the general population, with sprint interval training shown to increase aerobic fitness and decrease body fat in inactive overweight/obese females (Rowley, et al., 2017), as well as reduce low-density lipoproteins (LDL) and total cholesterol in young healthy participants (Sandvei et al., 2012). Therefore, assessment of RSA responses in different MC sub-phases has important practical and theoretical implications. From a practical point of view, knowing how different aspects of performance are influenced by MC sub-phases could help coaches and sport scientists to tailor their schedules and programs in order to maximize performance. From a theoretical point of view, it could benefit future researchers in this under-researched field by informing future research design and providing new data for comparison purposes.

Therefore, the aim of this study was to measure physiological, performance and perceptual responses during RSA at the early-follicular (EF) and mid-luteal (ML) sub-phases of the MC. These two MC sub-phases were chosen as they exhibit the greatest hormonal differences, allowing a clearer understanding of the effects these may have on any measured variable (Julian et al., 2017). It was hypothesized that the MC sub-phases will affect physiological parameters, but not the performance and perceptual measures. Specifically, it is expected that heart rate will be lower during the EF sub-phase. In contrast, lactate values will be lower during the ML sub-phase compared to the mid-follicular sub-phase, with no changes in $\dot{V}O_2$, power output, acceleration, distance or rating of perceived exertion (RPE) between the sub-phases.

METHODS

Participants

Five healthy, non-smokers, physically active participants (25.4 ± 3.0 years; 1.65 ± 0.1 m; 64.5 ± 18.6 kg; 43.2 ± 5.2 ml $O_2 \cdot kg^{-1}$) participated in this study. The inclusion criteria for participation in the study were (a) the presence of regular (24 to 35 days) eumenorrheic menstrual cycles for no less than one year, (b) the absence of any form of hormonal contraception for at least four months, (c) menstruating for at least three years, (d) training at least three times per week for a full year (any form of training), (e) not under any medication or treatments that could influence hormones or performance.

The participants were asked to abstain from caffeine, alcohol, and heavy exercises during the 24h before each of the sessions and were instructed to keep their normal dietary habits. Participants were also instructed to drink 500 ml of water 1 h prior to each session, to ensure hydration. Prior to testing all participants were asked to complete the American College of Sports Medicine (ACSM) Exercise Preparticipation Health Screening Questionnaire for Exercise Professionals and provide written consent to verify eligibility for the study. The research and procedures were approved by the Edinburgh Napier University Ethics Committee (SAS0081) and were performed in regulation with the Declaration of Helsinki for Medical Research involving human participants.

Design

Participants reported to the Sport and Exercise Science laboratory on seven occasions: an initial session to measure VO_2peak, 2 familiarization sessions, and 2 sessions for each sub-phase (EF and ML). The mean values of every parameter from the two interventions in each session of the same sub-phases were used for the comparison between EF and ML during the statistical analysis.

All the sessions were conducted in the Sport and Exercise Science laboratory in a controlled environment (temperature: 20.92 ± 0.97 °C, humidity: 32.79 ± 9.54 %) and were successfully completed by every participant but one, who could not complete the second session of ML. Four out of five participants had their first sessions during EF, and one, indicated as "P5" in Figure 1 and 2, started during ML.

During the familiarization and intervention sessions, participants performed the same protocol with at least 24h of rest between consecutive sessions. Physiological, perceptual and performance data were collected during all sessions to check repeatability of measures, and to indicate that any changes between the interventions were not due to the learning effect.

Procedures

Peak Oxygen Uptake Test

Participants' VO2peak was initially determined using an incremental test to exhaustion on a motorized treadmill (Ergo ELG-55, Woodway, Germany), performed to volitional exhaustion. Following a five minute standardized warm-up, running at a constant speed of 9.6 km/h at 0% gradient, the speed was increased to 11.2 km/h where the set speed remained, and every two minutes the gradient was increased by 2.5% (Kavaliauskas et al., 2015; Taylor et al., 1955). During the test, exchanged air was analysed using a breath-by-breath gas analyzer (Metalyzer 3B, Cortex, Leipzig, Germany). The Cortex was prepared following the manufacturer's instructions, performing the calibration approximately 30 minutes before every use.

Determination of the Menstrual Cycle Phases

The procedure to predict and determine the MC phases started immediately after the first visit. A combined approach adapted from Lara et al. (2019) using an electronic diary (FitrWoman, https://www.fitrwoman.com/, Orreco Limited, Ireland) and a urinary kit (Clearblue Advanced Digital Ovulation Test, SPD Swiss Precision Diagnostics, Geneva, Switzerland) was chosen for this project, in order to increase the chances to detect ovulation (Mattu et al., 2019; Wideman et al., 2013). The participants started to use the electronic diary immediately after the first visit, and the urinary kit after the first menstruation following the third visit. The EF sub-phase was determined being two days from the beginning of the menstruation until the seventh day (Janse de Jonge, 2003). Once ovulation was indicated, the ML sub-phase was classified as four to ten days post ovulation (Janse de Jonge, 2003; Köse, 2018; Pestana et al., 2017; Stefanovsky et al., 2016).

Repeated Sprint Ability Intervention

At the arrival to the laboratory for all testing sessions,

a blood lactate measurement was taken at rest using the Lactate Pro 2 LT-1730 (Arkray Factory Inc., Kyoto, Japan). Blood was collected by puncturing the fingertip of the participants with a lancing device. The first drop of blood was wiped, with the second drop being collected using a lactate strip that absorbed 0.3µL of blood. The strip was then inserted in the lactate analyzer to provide a blood lactate value after 15 seconds. Following the blood lactate measurement, the participant's height was measured to the nearest 1cm using a stadiometer (Harpenden Portable, Holtain Limited, Dyfed, UK), whilst body mass was measured to the nearest 0.1 kg using a mechanical column scale (SECA 711, Hamburg, Germany). During the collection of anthropometric data, participants were asked to dress as light as possible, and to remove their shoes to measure their body mass. Furthermore, participants were invited to void their bladder prior to the beginning of the measurements, to ensure replicability.

Waist and hip circumferences were also measured using a body tape (SECA, Hamburg, Germany). A bioelectrical impedance analysis (BIA) system (Quadscan 4000, Bodystat, UK) was used to measure body composition. Waist circumference was measured at the narrowest point of the waist, whilst the hip measurement was made at the largest part of the buttocks, and both the measurements were made keeping the tape horizontal to the ground (Wang et al., 2003; WHO, 2008). The measurement points were assessed visually by the same researcher.

After these measurements, the participants performed a standardized warm up of five minutes running at a self-selected speed on a non-motorized Force treadmill (Force 3.0, Woodway, Germany), before performing the RSA intervention. The RSA protocol consisted of five 'all-out' sprints of six seconds on the non-motorized treadmill with 24 seconds of active recovery (walking) between the sprints (McGawley & Bishop, 2006). The participants were verbally encouraged throughout the exercise, and they were given verbal instructions by the researcher about what to do in each phase.

During the test, a breath-by-breath gas analyzer (Metalyzer 3B, Cortex, Leipzig, Germany) was used to measure exchanged air continuously, and the heart rate was continuously monitored using an H7 Bluetooth Polar HR monitor (Polar, Kempele, Finland), following the same procedures utilized during the peak oxygen uptake test. For every parameter, the

mean value during each sprint without including rest periods was used for analysis. Moreover, during the recovery time between the sprints the RPE data were collected using the 6-20 Borg scale, by asking the participant to verbally give a number between six and 20 (Borg, 1982).

Performance data collected by the treadmill included power, acceleration and distance every 0.005 seconds. Mean values for power output (MPO) during each sprint, peak values for power output (PPO) and acceleration during each sprint, and distance were used for analysis. The fatigue index was calculated for peak power output, using the following formula (Glaister et al., 2008):

$$S_{dec} = \left\{ \frac{(S_1 + S_2 + S_3 + \cdots + S_{final}}{S_{best} \; x \; Number \; of \; sprints} - 1 \right\} x \; 100$$

After the intervention, three additional measures of blood lactate were performed following the same procedures and using the same materials explained previously. The first measure was done immediately after the exercise, the second one after three minutes and the last one after five minutes after the exercise completion.

Statistical Analyses

All statistical analyses were carried out using Jamovi (Version 1.6) with statistical significance being set at $p \leq 0.05$. Mean and standard deviations were calculated for all variables assessed. A Wilcoxon matched-pairs signed ranks test was performed to determine the significance of the differences between the two MC sub-phases. The magnitude of differences were evaluated by calculating the effect size (*r*) according to Rosenthal (1991) and interpreted based on the following criteria: <0.19, trivial; 0.20-0.49, small; 0.50-0.79, medium; and >0.80, large (Cohen, 1988; Fritz, 2012). The calculation for the effect size was established using the following equation:

$$r = \frac{Z}{\sqrt{N}}$$

RESULTS

No significant differences between EF and ML were found in any of the anthropometric parameters analysed (BMI and fat mass) (Table 1).

Significant differences between EF and ML were found in post-exercise lactate (EF: 12.7 ± 3.11 mmol·l⁻¹, ML: 11.2 ± 1.31 mmol·l⁻¹, $p = .04$, $r = .38$) (Table 2, Figure 1). However, the effect size was found to be small, showing that the differences might not be meaningful (Table 2). In contrast, non-significant differences were found in HR, pre-exercise lactate and VO_2 (Table 2).

The performance did not significantly differ between EF and ML, as shown by all the parameters analysed.

No significant differences between the two sub-phases were found in MPO, PPO, peak acceleration, distance and the fatigue index for PPO (Table 3).

Even though the performance parameters did not significantly change, significant differences between EF and ML were found in RPE (EF: 13.42 ± 2.15, ML: 12.60 ± 2.26, $p < 0.001$, $r = .46$) (Figure 2). However, the effect size was small, indicating that the differences might be meaningless (Figure 2).

Table 1. Anthropometric Parameters of All the Participants in Both the MC Sub-Phases

Parameter	Early-follicular	Mid-luteal	p	r
BMI (kg·m⁻²)	23 ± 5	24 ± 5	.35	.45
Fat mass (%)	24.5 ± 8.9	23.9 ± 10.5	1.0	.04

Table 2. Physiological Parameters of All the Participants in Both the MC Sub-Phases

Parameter	Early-follicular	Mid-luteal	p	r
Heart rate (BPM)	159 ± 20.4	157 ± 20.1	.06	.26
Pre-exercise lactate (mmol·l⁻¹)	1.43 ± 0.46	1.62 ± 0.57	.63	.21
Post-exercise lactate (mmol·l⁻¹)	12.7 ± 3.11	11.2 ± 1.31	.04	.38
VO2 (ml·kg⁻¹·min⁻¹)	35.7 ± 8.68	34.3 ± 8.92	.69	.06

Figure 1. Comparison of Post-Exercise Lactate between Participants (P) During the Early-Follicular (EF) and Mid-Luteal (ML) Sub-Phases of the MC.
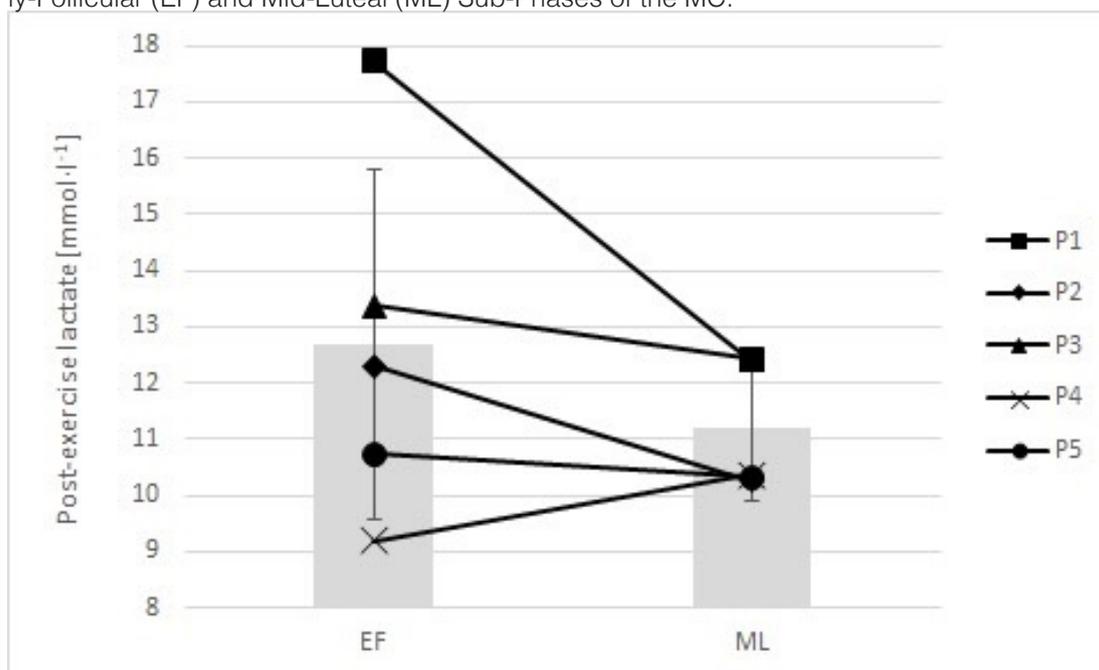
Table 3. Performance Parameters of All the Participants in Both the MC Sub-Phases

Parameter	Early-follicular	Mid-luteal	p	r
MPO (W)	1406 ± 209	1418 ± 231	.35	.14
PPO (W)	2498 ± 384	2474 ± 446	.38	.13
Sdec PPO	-6.91 ± 2.13	-4.76 ± 1.05	.19	.47
Peak acceleration (m·s^{-2})	4.65 ± 0.85	4.91 ± 1.18	.10	.23
Distance (m)	20.5 ± 2.44	20.5 ± 2.67	.95	.01

Figure 2. Comparison of RPE between Participants (*P*) During the Early-Follicular (EF) and Mid-Luteal (ML) Sub-Phases of the MC. (EF: 13.42 ± 2.15, ML: 12.60 ± 2.26, *p* < 0.001, *r* = .46).
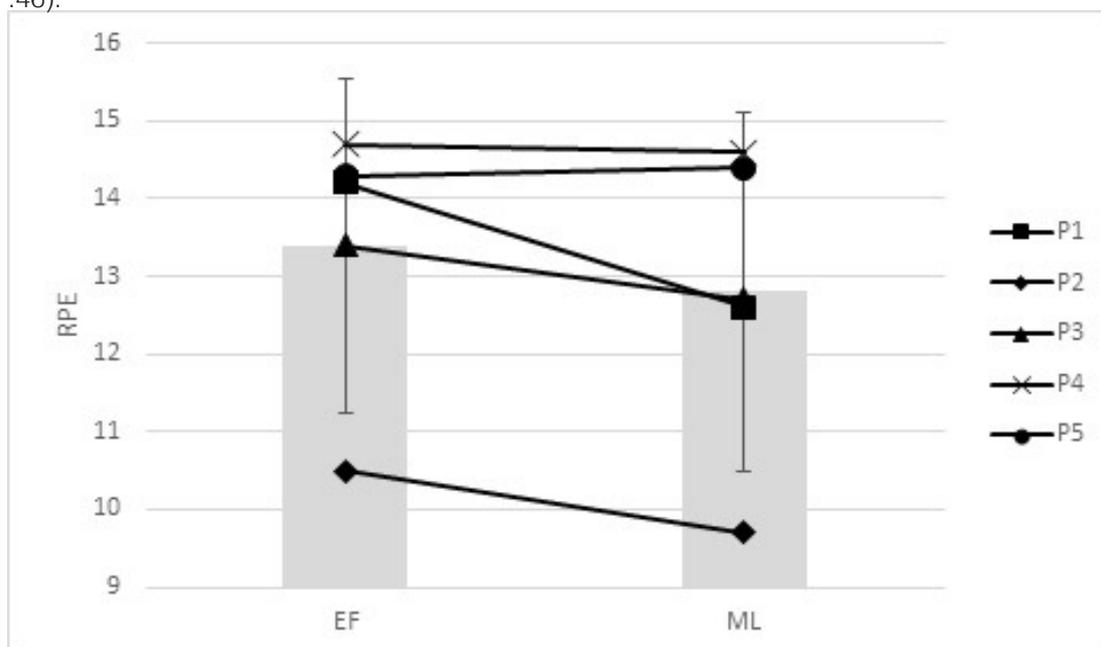
DISCUSSION

The purpose of this study was to investigate whether the MC phases affect RSA performance. The results show that RSA performance is not influenced by the MC sub-phases. Specifically, there were non-significant differences between EF and ML sub-phases in most anthropometric (Table 1), physiological (Table 2), and performance parameters (Table 3). However, significant differences between the MC sub-phases were found in post-exercise lactate level (EF: 12.7 ± 3.11 mmol·l^{-1}, ML: 11.2 ± 1.31 mmol·l^{-1}, *p* = .04, *r* = .38) (Table 2) and RPE (EF: 13.4 ± 2.15, ML: 12.8 ± 2.30, *p* = .001, *r* = .46) (Figure 2).

Even though previous studies about the effects of MC on RSA performance analyzed different parameters, they reached the same conclusion that the MC does not affect RSA performance. Tounsi et al. (2018) reported no significant differences in mean sprint time between the EF, late-follicular and luteal phases, and Ghazel et al. (2022) reported no significant differences in mean sprint time, best sprint time and sprint decrement between the EF, mid-follicular and ML phases.

Anthropometric Results

Body mass and fat mass were investigated due their relationship with RSA performance, which is negatively influenced by an increased body mass and fat mass (Fernando et al., 2016). As the results from this study show non-significant differences in any of the body composition parameters analysed (Table 1), it appears that from an anthropometric point of view the MC does not affect RSA performance. As hypothesized by Janse de Jonge (2003) and Giacomoni et al. (2000), it is possible that the MC effect on fluid regulation might not be enough to significantly affect body composition. The findings of the present study agree with previous studies that did not find any differences in body composition between EF and ML (Beidleman et al., 1999; Bemben et al., 1995; De Souza et al., 1990; Julian et

al., 2017; Lebrun et al., 1995). The respectively small and trivial effect sizes found in BMI (r = .45) and fat mass (r = .04) (Table 1) reinforce the conclusion that the hormonal fluctuations during the MC do not meaningfully influence body composition.

Physiological Results

The non-significant heart rate (HR) results (EF: 159 ± 20.4 BPM, ML: 157 ± 20.1 BPM, p = .06, r = .26) (Table 2) contrast with our hypothesis of a lower heart rate during the performance of a RSA test during EF when compared with ML. As progesterone has been found to increase heart rate, we hypothesized that a higher HR would be found during the luteal phase during testing, where the concentrations of progesterone are higher (Pivarnik et al., 1992; Sedlak et al., 2012). However, the results agree with the previous studies that did not report significant differences in HR between the EF and ML sub-phases (Abdollahpor et al., 2013; Beidleman et al., 1999; Bemben et al., 1995; De Souza et al., 1990; Dean et al., 2003; Lebrun et al., 1995; Oosthuyse et al. 2005). It is possible that the difference in progesterone concentration between the two sub-phases was not enough to significantly affect HR. Another possible explanation is provided by Janse de Jonge et al. (2012), whom suggested that HR would be affected by changes in body temperature between the follicular and luteal phases. However, the average increase of temperature during the luteal phase within our study (up to 0.6 °C) might be too low to significantly affect HR. The small effect size (r = 0.26) further supports the conclusion that MC sub-phases do not significantly and meaningfully affect HR when performing RSA.

Similarly, to HR and in agreement with our hypothesis, no significant differences in $\dot{V}O_2$ were found (EF: 35.7 ± 8.68 ml·kg^{-1}·min^{-1}, ML: 34.3 ± 8.92 ml·kg^{-1}·min^{-1}, p = .69, r = .06) (Table 2). Janse de Jonge (2003) offered an explanation by hypothesizing that VO2max would be affected by the MC only if the determinants of $\dot{V}O_2$max such as HR were also affected. Even though the author was specifically referring to $\dot{V}O_2$max, a link between HR and VO2 is strong (Bot & Hollander, 2000; Freedson & Miller, 2000; Habibi et al., 2014), which is demonstrated by our findings as no significant differences in HR are also reflected in no significant changes in $\dot{V}O_2$. This finding suggests that potential cardiovascular changes related to MC hormonal fluctuations are not associated with changes in oxygen uptake during repeated sprints (Gurd et al., 2007).

Significant differences were found in post-exercise lactate (EF: 12.7 ± 3.11 mmol·l^{-1}, ML: 11.2 ± 1.31 mmol·l^{-1}, p = .04, r = .38) (Table 2, Figure 1) but non-significant differences were found in pre-exercise lactate (EF: 1.43 ± 0.46 mmol·l^{-1}, ML: 1.62 ± 0.57 mmol·l-1, p = .63, r = .21) (Table 2). Whilst it is possible to hypothesize that the MC might have affected lactate production during and after the exercise, and not basal levels, further analysis of the data showed that one participant (P1, Figure 1) had a high difference in post-exercise lactate (5.33 mmol·l-1) between EF and ML, that significantly affected the results (Figure 1). In fact, if this participant is removed from the analysis, the result would change and the difference in post-exercise lactate between EF and ML would be non-significant. For this reason, the authors argue that despite the significant result, the MC does not affect post-exercise production. The effect sizes from post- (r = .38) and pre-exercise lactate (r = .21) were both small, further supporting the conclusion that the MC does not affect lactate and that the significant post-exercise lactate result might be caused by an outlier (Figure 1). These conclusions agree with previous literature, which reported non-significant differences in lactate between EF and ML (Abdollahpor et al., 2013; Bemben et al., 1995; De Souza et al., 1990; Dean et al., 2003; Lamont, 1986). As oestrogen and progesterone have been shown to affect energy metabolism and substrate utilisation, and therefore lactate levels, significant differences were expected (D'Eon et al., 2002; Kalkhoff, 1982; Oosthuyse et al., 2005). A possible explanation is that, even though oestrogen and progesterone can affect lactate levels, the hormones difference between EF and ML were not big enough to show any significant difference. This lack of differences between sub-phases suggests that no metabolic changes (higher fat utilisation) occurred between EF and ML, but more studies with a higher sample size are needed to confirm these conclusions.

Performance Results

Non-significant differences between EF and ML were found in MPO (EF: 1406 ± 209 W, ML: 1418 ± 231 W, p = .35, r = .14) and PPO (EF: 2498 ± 384 W, ML: 2474 ± 446 W, p = .38, r = .13) (Table 3). As power output might be affected by changes in body composition (Pestana et al., 2017), the lack of significant differences between EF and ML in body composition are in line with non-significant differences found in power output.

Thus, providing a possible explanation about why

the MC does not affect power output. The findings agree with those by Köse (2018), who reported non-significant differences between the same sub-phases during a Wingate anaerobic test, in mean and peak power output. Even though the Wingate anaerobic test and running RSA do not appear to be correlated (Aziz & Chuan, 2004) and acknowledging the differences between running and cycling, both tests measure anaerobic power output and, due to the lack of other relevant research studies, the results were used for comparison purposes.

Middleton and Wenger (2006) analyzed an RSA performance and reported non-significant differences in peak power between the mid-follicular (6.8 ± 0.6 W·kg^{-1}) and late-luteal (6.9 ± 0.6·kg^{-1}) sub-phases, reaching the same conclusions as the present study. Even though different sub-phases were analysed, the results reported by Middleton and Wenger (2006) strengthen the conclusion that the MC might not influence power output.

In contrast, Graja et al. (2020) reported a decrease in peak power during the premenstrual phase compared with the late-follicular and ML phases, and during the ML phase compared with the late-follicular phase. However, these differences appear to be significant only in the last 6 sprints out of 20 of their protocol, showing that the effects of the MC on RSA could be more evident when fatigue occurs (Graja et al., 2020).

In agreement with our hypothesis, no significant differences in peak acceleration between EF and ML were found (EF: 4.65 ± 0.85 m·s^{-2}, ML: 4.91 ± 1.18 m·s-2, p = .10, r = .23) (table 3). As there is no literature about the effects of the MC phases on acceleration, we based our hypothesis on previous literature about parameters correlated with acceleration such as power output (Pavei et al., 2019). Considering that power output has been positively linked with acceleration (Pavei et al., 2019) and that previous literature showed that the MC does not affect power output, we did not expect to see any significant differences in peak acceleration. Similarly, distance did not differ between EF and ML (EF: 20.5 ± 2.44 m, ML: 20.5 ± 2.67 m, p = .95, r = .01) (Table 3). This lack of significance can be explained by the fact that power output or acceleration rates were non-significant. In fact, a strong relationship between power output and sprint performance exists, especially for short sprints (Haugen et al., 2019). To our knowledge, no studies tested sprint performances and reported distance as a parameter, and therefore a comparison with previous literature is not possible.

The non-significant results from MPO, PPO, peak acceleration and distance (Table 3) are in agreement with our hypothesis, and might indicate that performances similar to RSA, relying on these parameters, should not be affected by MC. This is further confirmed by their effect sizes (Table 3), that were found to be trivial (MPO: r = 0.14, PPO: r = 0.13, distance: r = 0.01) or small (peak acceleration: r = 0.23).

Perceptual Results

The hypothesis that no differences would be found in RPE between EF and ML was not supported, as a significantly lower RPE was found during ML when compared with EF (EF: 13.42 ± 2.15, ML: 12.60 ± 2.26, p < 0.001, r = .46) (Figure 2). The hypothesis was based on previous literature that did not report any differences in RPE between EF and ML (Beidleman et al., 1999; De Souza et al., 1990; Janse de Jonge et al., 2012).

To explain the significant differences in RPE in this study, the most likely explanation would be the learning effect, where the participants became more familiar with the test despite the two familiarization sessions. The two familiarization sessions may have not been enough for the participants to feel comfortable with the protocol and the non-motorized treadmill, and it is possible that the participants needed more than the two sessions provided to be ready to perform without seeing the influence of the learning effect. This is further confirmed by the fact that, despite the randomization process, all participants reported a higher RPE levels in the first testing session. The results showing a higher RPE during EF can be explained by the unbalanced number of participants being tested in EF before ML. Due to the drop-out, 4 out of 5 participants were tested in EF first, leading to a significant difference when compared to ML. If more familiarization sessions were used, it is possible that the differences between EF and ML would decrease and become non-significant.

Even though RPE and post-exercise lactate were found to be significantly different between the EF and ML phases of the MC, the fact that the other parameters did not show significant differences suggests that RSA is largely unaffected by the MC. However, this may be explained by the low variability in the hormone's concentrations between the two sub-phases, which led to nonsignificant effect.

Practical Implications

The non-significant differences and small/trivial effect sizes found in almost every parameter indicate that the performance is not affected by the MC sub-phases, and therefore coaches and athletes should not tailor their RSA training and testing on the MC. However, this interpretation of the results is strictly related to the outcome of the performance (i.e., distance in each sprint) and does not properly consider the psychological aspects behind the performance and trainings and therefore might be limited. Even though from the current study and the existing literature it appears there are no differences in physiological and performance parameters, Findlay et al. (2020) outlined that several athletes felt their performance to be negatively impacted. Findlay et al. (2020) reported that 93% of the participants reported negative MC related symptoms such as worry, distraction and lack of motivation, and 67% of the participants considered that those symptoms impaired their performance. Furthermore, two participants reported that they were not able to complete a training session due to pain or dysmenorrhea (Findlay et al., 2020). This might negatively impact athletes' performance level, especially if this occurs at multiple times during the competitive season.

Therefore, practitioners should take these perceptions into consideration when working with female athletes. The coach-athlete relationship is fundamental and addressing what an athlete reports might help build a relationship of trust as well as optimize their training program. In contrast, ignoring how they feel might lead to sub-optimal performance. The coaching staff should follow an evidence-based approach by monitoring each athlete's MC, openly discussing the possible effects of MC on performance, and where required adapting their training programs based on the athletes' subjective feelings. A personalized approach based on each athlete's responses to the MC and performance is therefore suggested as the best option with the current evidence available.

Limitations

The small sample size limited the statistical power of this study. Therefore, to strengthen the results, each test was repeated twice during each MC sub-phase. The second limitation is the determination of the MC sub-phases, as the combined approach chosen did not guarantee the exclusion of luteal phase deficient participants and did not provide hormonal values to be used to confirm the MC sub-phases. Another limitation is that the sessions were not done at the same time of the day, due to participants' personal reasons, exposing the results to circadian variations in hormonal fluctuations, potentially affecting the results. Due to these limitations, the results must be interpreted with caution. However, as there were no previous studies about the effects of the MC on repeated sprint ability, these results provide a first insight into the effects of EF and ML sub-phases on RSA.

Conclusions

Our data showed that the MC sub-phases did not affect RSA anthropometric, physiological, performance and perceptual parameters. Due to the very limited literature available, and the several limitations present in the literature around the effects of the MC on performance, larger, well-controlled studies are required. Future research should address the major limitations, and consider perceptual and psychological parameters, to better understand their impact on performance and training and how it changes throughout the MC.

CONFLICTS OF INTEREST

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