The influence of menstruation on training schedules in well-trained and elite female mountain bike, road and cyclocross athletes

Robyn Aitkenhead

A Masters by Research Thesis

Submitted in partial fulfilment of the requirements for the award of Master by Research of Edinburgh Napier University

March 2022

Abstract

Female physiology is unique and driven by fluctuations in sex hormones that regulate the menstrual cycle (MC) (Marsh et al., 2002). These hormones present a myriad of mechanisms that may influence physiological systems, potentially implicating exercise performance. However, research exploring the MC in athletes is limited. This study investigated if different phases of the MC influenced training schedules, sleep quality, arousal and alertness in elite female mountain bike, road and cyclocross athletes. The study was approved by Edinburgh Napier University's ethics committee. Fifteen well-trained (N=7) and elite (N=8) cyclists (age: 29 ± 7.4 years, height: 1.7 ± 0.1m, body mass: 61.9 ± 7.7kg) tracked their MC symptoms, basal body temperature (BBT), body mass, perceived sleep, and psychological measures daily for 3 months. The MC was split into two phases, follicular (FP) and luteal (LP), and participants were provided ovulation kits to identify the phases. Athlete's BBT was significantly higher ($p<0.05$) in the LP (0.21ºC, $p=0.00$, $d=0.4$). No significant differences in body mass (FP; 61.8 ± 6.0, LP; 61.0 ± 6.6), sleep duration (FP; 8.0 ± 1 hrs, LP; 8.0 ± 1 hrs), perceived sleep quality (FP; 7 (7-7.8), LP; 7 (7-8)), alertness (FP; 6 (5-7), LP; 7 (6-7)) and arousal (FP; 3 (2-5), LP; 3 (2-5)) were observed. Further, no significant differences for any training variables, average heart rate (FP; 128 ± 37 bpm, LP; 128 ± 38 bpm), training load (bTRIMP) (FP; 173.5 ± 148.6 A.U, LP; 189.8 ± 158.3 A.U), average speed (FP; 19.3 ± 15.6 km.hr, LP; 18.8 ± 9.0 km.hr) and rating of perceived exertion (RPE) (FP; 13.2 ± 2.7, LP; 13.4 ± 3.0) were observed. Several limitations

of this study included the lack of hormonal verification underpowered, and a larger cohort with an even discipline split is required to determine more significant values. In conclusion, the MC does not influence physiological responses and training variables in well-trained and elite mountain bike, road and cyclocross female athletes.

Acknowledgements

Firstly, I would like to thank my supervisor Dr Lesley Ingram-Sills for her support and guidance over the last year and more. I have learnt a lot from her expertise and very grateful for her time and hard work. And a further thank you to Prof Geraint Florida-James and Dr Lewis Kirkwood for their feedback and support. An extra thanks to Lewis for his guidance on how to use R for data analysis, a new skill I am thankful to have learnt.

A huge thank you to all of my participants who took part in the study for 3 months, without their dedication and hard work I would not have a thesis to write.

Thank you to my friends and family for their constant support. To Mark for helping me learn how to program in RStudio and dealing with all of my mini breakdowns when it didn't always go my way. A special thanks to Siobhan, a close friend who was always there to support me whenever I needed her, and I enjoyed going through the MRES process together. And of course, a thank you to my parents who are always supporting me and my aspirations.

Contents

List of tables

List of figures

List of abbreviations

ANOVA	analysis of variance
aPVT	auditory psychomotor vigilance task
A.U.	arbitrary units
BBT	basal body temperature
BMI	body mass index
DH	downhill
EWS	enduro world series
FP	follicular phase
HR	heart rate
HR_{max}	maximum heart rate
hrs	hour(s)
kg	kilogram
LEAF-Q	low energy availability in females questionnaire
LP	luteal phase
LH	luteinizing hormone
m	meters
MC	menstrual cycle
OP	ovulatory phase
NREM	non-rapid eye movement
RED-S	relative energy deficiency
REM	rapid eye movement
RER	respiratory exchange ratio
RPE	rating of perceived exertion
SFI	Subcutaneous fatness index
UCI	Union Cycliste Internationale
$\dot{V}O2_{max}$	maximal oxygen consumption
XC	cross country
XCO	cross country Olympic

Chapter 1: Introduction

The menstrual cycle (MC) is an essential biological process for females which involves a repeating pattern of sex hormone production and secretion (Marsh and Jenkins 2002). The MC typically lasts 28 days but can range from 21-35 days and is divided into three main phases: follicular phase (FP), ovulatory phase (OP), and luteal phase (LP) (McNulty et al., 2020; Marsh et al., 2002). Each phase is regulated by sex hormones including oestrogen and progesterone. These hormones influence many physiological systems, and research has proposed a myriad of mechanisms that could therefore affect performance (Hackney, 1999; Mash et al., 2002; Hashimoto et al., 2014).

The FP is characterised by an increase in oestrogen, which influences energy metabolism, increasing muscle glycogen storage and uptake and in turn, benefiting short-term high-intensity exercise (Hackney, 1999; Oosthuyse et al., 2005). However, it has also been recognised that increased oestrogen may benefit submaximal endurance exercise due to an increased reliance on free fatty acids (Hackney et al., 2022). During the LP, progesterone counteracts oestrogen's mechanisms and leads to enhanced reliance on fat oxidation, benefiting prolonged endurance exercise (Hackney et al., 2020). A rise in progesterone also leads to a greater thermogenic effect leading to a rise in body temperature, which may have a negative impact on prolonged performance and a quicker onset of fatigue (Janse de Jonge, 2003; Charkoudian & Stachenfeld, 2016). Current research on short-term and long-duration performance are mixed, both Campbell, Angus and Febbraio (2001) and Oosthuyse et al. (2005) observed a trend for improved cycling time trial performance in the FP compared to the LP in recreationally trained females. It may be postulated that this resulted from progesterone's anti-oestrogenic effect and the subsequent rise in body temperature during the LP. Conversely, Vaiksaar et al. (2011) observed no difference in endurance performance during an incremental rowing test, detailing that the MC does not influence endurance performance. In addition, Middleton and Wenger (2006) revealed improved sprinting ability in the LP; however, García-Pinillos et al. (2021) and Rael et al. (2021) detected no change in sprinting performance.

As well as anaerobic and aerobic performance, strength and power are also important measures for optimal mountain biking performance. A recent meta-analysis by Blagrove, Bruinvels and Pedlar (2020) highlighted that there are minimal strength-related changes across the MC. One previous study by Pallavi et al. (2017) detected an improved grip strength during the FP compared to the LP in recreationally trained females. However, differences within the studies may have been a consequence of many factors, including low participant number (Oosthuyse et al., 2005; Middleton et al., 2006, García-Pinillos et al., 2021), training levels ranging from untrained or recreationally trained (Campbell et al., 2001; Middleton et al., 2006; Pallavi et al., 2017) to well-trained (Vaiksaar et al., 2011) and the wide variety of sporting disciplines including running (Rael et al., 2021), rowing (Vaiksaar et al., 2011) cycling (Oosthuyse et al., 2005) and strength training (García-Pinillos et al., 2021). In addition to low-quality methods used to identify the MC phases and the study's length such as primarily using calendar-based counting (García-Pinillos et al., 2021). All of the above research measured performance across one MC however, BASES expert statement in 2020 (Elliot-Sale et al., 2020) highlighted the MC should be monitored for at least three months to provide a reliable and realistic picture of the effects on training and performance. However, no research has investigated athletes' training and performance across three consecutive cycles.

Research investigating the MC in elite populations is limited. Many researchers have avoided exploring female physiology, and only 6% of studies have included exclusively female athletes (Mujika & Taipale, 2019). Consequently, a plethora of MC research focuses on untrained females or recreational athletes across various disciplines (Emmonds et al., 2019). To date, no study has investigated the influence of the MC in elite female mountain bike or road cyclists.

Female participation in sport is rising, specifically at high performance and elite levels. In the 2016 Rio Olympic Games, female participation was at 45%, compared to 11% in the 1960 Rome Olympic Games (Meignie et al., 2021). The increase in participation has subsequently led to greater opportunities for females in sport and in 2021 an equal number of Union Cycliste Internationale (UCI) races were available for female and male elite cyclists. Mountain biking encompasses several disciplines, including cross country (XC), enduro, marathon, downhill (DH) and freeride. Each discipline presents similarities however, the physiological profiles will vary to meet the specific demands of the sport (Impellizzeri et al., 2007). Firstly, XC is an Olympic sport and is the most well-known and researched discipline. Riders will complete laps of around 4 to 6 km, consisting of steep climbs and descent. Marathon follows similar off-road terrain but covers much longer distances, ranging from 40 to 140 km (UCI, 2019). Enduro mountain biking was first introduced in 2013 at the Enduro World Series (EWS). Events occur over one to two days, with races lasting between 3 to 9 hours. Riders will complete multiple timed downhill stages with time-constrained uphill transitions (Kirkwood et al., 2017). Further, DH has a greater technical demand than XC and enduro, and riders will produce shorter bouts of power, requiring a high anaerobic capacity (Chidley et al., 2015). Riders will cover a maximum distance of 3.5 km, lasting 2 to 4 minutes (Hurst & Atkins, 2006). Freeride mountain biking is considered a subset of DH, and riders will complete descending trails including many obstacles and are considered much more technical than DH and XC (Becker & Moroder, 2017).

There has been a lack of guidance about what constitutes an elite athlete. Previously, Decroix and De Pauw et al. (2016) used athletes' training experience and volume to define training status. The authors proposed that elite female cyclists will have a training background of at least six years and train a minimum of five times per week (Decroix et al., 2016). Additionally, a new framework by Mckay et al. (2022) has evolved, stating that world-class and elite classifications require athletes to be competing internationally and sit between top rankings of 1 to 300, based on the size of the competition. Specific to mountain biking, Mckay et al. (2020) stated that elite status should be classified from rankings and placings at major competitions (Mckay et al., 2022).

Elite athletes account for the top 5% of their sport (Burden et al., 2021), and consequently, research investigating the effect of the MC on elite female athletes is limited. It is evident that cyclic fluctuations in oestrogen and progesterone influence physiological systems however, the influence on performance is equivocal. A large proportion of the current research is based on short-term studies investigating one MC and are conducted in a lab-based environment or through written questionnaires. More longitudinal studies investigating at least three cycles and examining performance within actual training environments are required to better understand the influence on training and performance measures. Elite female cyclists will endure high-intensity training schedules year-round and to date and no research has determined how the MC influences elite female cyclists' training and performance. Therefore, by conducting a three-month observational study, a greater understanding of the role the MC hormones have on female cyclists training physiologically and psychologically will be provided. This will offer future direction for research investigating the MC's effects on well-trained and elite female cyclists.

Chapter 2: Literature Review

2.0 Introduction and search strategy

Female participation and opportunities in mountain biking is growing in popularity at a recreational and an elite level (UCI, 2022). Yet, how the physiological demands of mountain biking influences the females MC remains unclear. To date, there is limited research investigating the influence of the MC on well-trained or elite athletes and an even further lack of evidence on how the MC may influence female mountain bike, road and cyclocross athlete's training schedules and performance. Therefore, this literature review aims to develop a clearer picture of the current evidence of the MC's effect on training and performance in female athletes across a wide array of sporting disciplines. The physiological demands of elite mountain biking, road cycling and cyclocross will take specific focus. In addition, MC identification methods, physiological and psychological responses to the MC, sleep and performance measures will be discussed.

Before the literature review was conducted, a general primary search was carried out to gain a sound understanding of the research around the influence of the MC on training and performance. Databases used were SPORTDiscus, Sports Direct, MEDLINE, ProQuest and PubMed. A 22-year date search (2000-2022) was carried out to represent the development of MC research and allow for the inclusion of pivotal studies within this time frame. An inclusion and exclusion criteria were set as follows. Inclusion: full-text articles with healthy humans, studies with female participants written in English and published within the 22-year search. Exclusion: studies with animals, children, pregnant or menopausal females, any participants with injuries, exclusively females using contraceptives and any studies affiliated with a company that may bias results. Keywords used were "*menstrual cycle", "menstruation", "luteal"," follicular", "mountain biking", "road cycling", "riding", "mountain biking", "cycling", "exercise", "performance", "female athletes", "elite athletes*" and were applied using Boolean operators including "AND", "OR" and "NOT" to select the studies. Based on the above information, a Prisma schematic of the search results is presented in Figure 1 below.

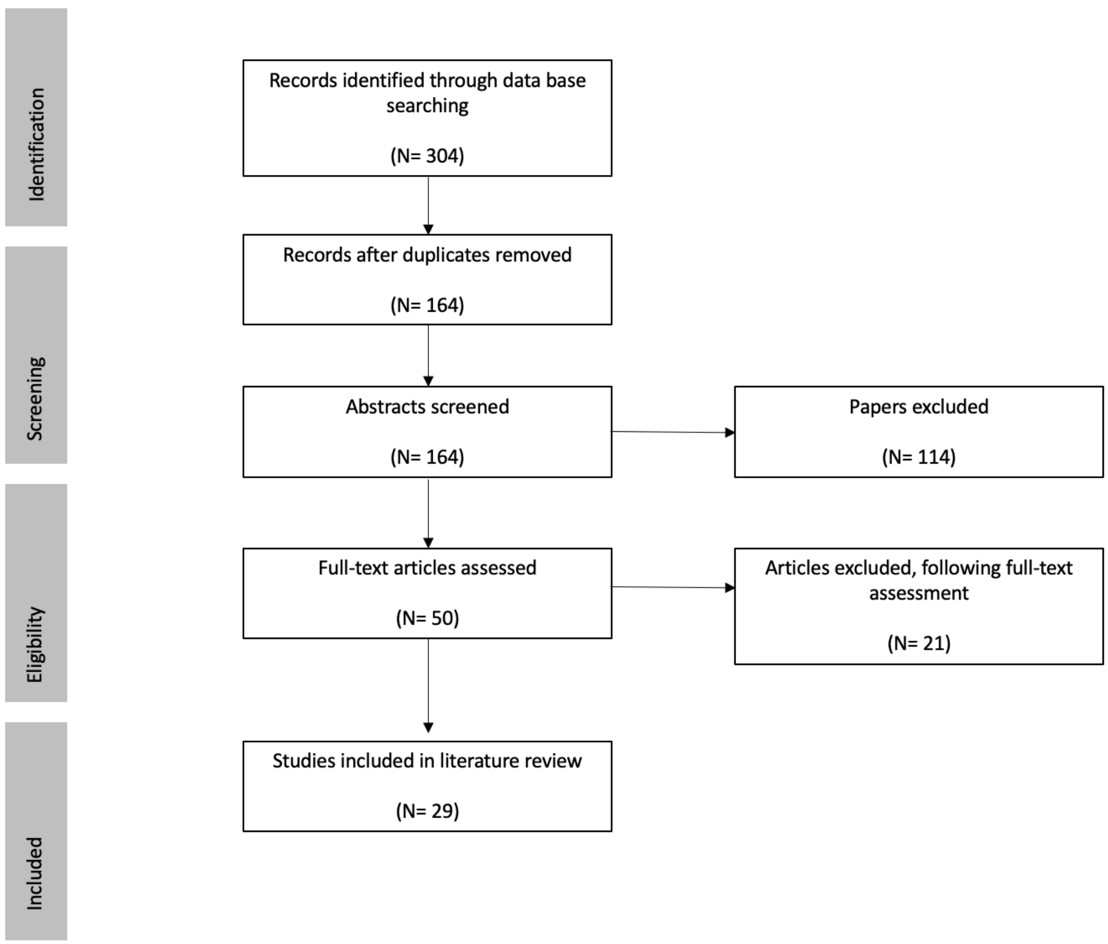


Figure 1: Prisma Schematic of search results

Of the 304 articles identified in the search, 164 articles were initially screened after removal of duplicates. A total of 114 articles were excluded as they did not meet the inclusion criteria. Following full text assessment, 21 articles were excluded with reasons including a focus on supplementation (N=6), primarily investigating contraceptive use (N=5), iron regulation (N=2), muscle function (N=3), injury and bone health (N=4) and menopause (N=1).

2.1 Physiological demands of mountain biking, road and cyclocross

Despite the growing popularity of mountain biking, very few studies have investigated the physiological demands between disciplines, especially in elite female riders. Mountain biking is a high-intensity sport which places a large physiological demand on riders (Impellizzeri & Marcora, 2007). The physiological responses for each mountain bike discipline will vary due to a wide range of terrain with technical difficulties, different pacing strategies and high speed or low speed pedalling for large climbs and descents (Impellizzeri et al., 2007; Hays et al., 2018).

Firstly, XC riders are required to maintain a strong maximal aerobic power and will sit above their lactate threshold for up to 80% of the race (Bejder et al., 2019). The high-intensity intermittent nature of XC will lead to riders going beyond their maximal aerobic power output for short bursts of 5-10 seconds. Therefore, both anaerobic and aerobic metabolic pathways are essential for optimal performance (Impellizzeri et al., 2007; Hays et al., 2018). Other physiological determinants will include strength, power and muscular endurance. Marathon is longer than XC and thus, the total distance and altitude climbed will be greater. Ahrend et al. (2018) observed that in a 1 minute maximal effort, power output, anaerobic threshold and athlete body weight explained 75% of performance. Furthermore, Carmo et al. (2021) recognised that work rate at the second ventilatory threshold explained 87% of race performance. Therefore, both aerobic and anaerobic systems will be vital for optimal performance during a marathon race.

Similar to XC, enduro athletes require a strong anaerobic and aerobic capacity; however, enduro is considered more technical than XC (Kirkwood et al., 2019). Events can last 3 to 9 hours, and riders may sustain an HR of >90% HR_{max} for up to 20 minutes during a race stage (Kirkwood et al., 2017). During the downhill stages of an enduro race, workload intensity may surpass the aerobic system and athletes may produce energy via the anaerobic glycolic pathway (Kirkwood et al., 2019). Subsequently, lactate concentration in the blood will increase in response to a rise in workload. Overall, enduro riders must exhibit a strong aerobic and anaerobic capacity to maintain the prolonged duration of the event and the short bouts of high-power outputs for each stage (Kirkwood et al., 2017, 2019).

Furthermore, DH will require a strong technical ability and skill to descend on the challenging terrain composed of rocky paths, jumps and vertical drops (Hurst et al., 2012). DH is a high-intensity intermittent discipline and riders will produce shorter bouts of power over durations of <15 seconds and require a high anaerobic capacity (Chidley et al., 2015). Along with anaerobic capacity, other determinates of DH performance are handgrip endurance, confidence and skill (Chidley et al., 2015). Freeride is a subset of DH mountain biking, primarily riding DH trails. Freeride athletes will complete large ascents requiring a strong aerobic capacity followed by fast-paced descents and thus encompass similar physiology characteristics to XC and DH riders. However, freeride is considered more technical as riders will endure much more obstacles than a DH rider (Becker et al., 2017).

Elite road cycling is a high-intensity discipline and can include short and long durations lasting from <15 minutes to >3 hours, on a variety of terrains (ie uphill, downhill, level) (Martin et al., 2001). During the female world tour, cyclists can cover 13000 to 18000 km throughout the year for both training and competition (Saunders et al., 2019). Elite riders will possess a high anaerobic and aerobic threshold as they carry out periods of high-intensity exercise at around 90% of their maximal volume of oxygen consumption (VO_{2max}) (Mujika et al., 2001; Martin et al., 2001). Riders will produce large power outputs throughout the entirety of the race and previously, elite females have shown a peak power output of 254-364 W (Lamberts et al., 2014). Finally, cyclocross is a blend of mountain biking and road cycling. Most cyclocross races are off-road courses (2.5 to 3 km) and last up to one hour. Races will exhibit a wide range of terrain and obstacles to navigate and a large amount of technical skill is required (Carmichael et al., 2017). Similar to other disciplines such as XC and enduro, riders will possess enhanced anaerobic and aerobic systems to allow for short bursts of power and recovery from high-intensity bouts to maintain for the duration of the race (Carmichael et al., 2017).

2.2 The menstrual cycle (MC)

The MC is a series of cyclic changes in hormones that drive the primary purpose of the MC, pregnancy (Marsh et al., 2002; Draper et al., 2018). As mentioned previously, the MC is broken down into three main phases, the FP, the OP and the LP. The MC is characterised by the three primary sex hormones which fluctuate during the MC; oestrogen, progesterone, and luteinizing hormone (LH) (Marsh et al., 2002; Draper et al., 2018). Figure 2 below presents the hormone fluctuations across the MC based on an idealised 28-day cycle.

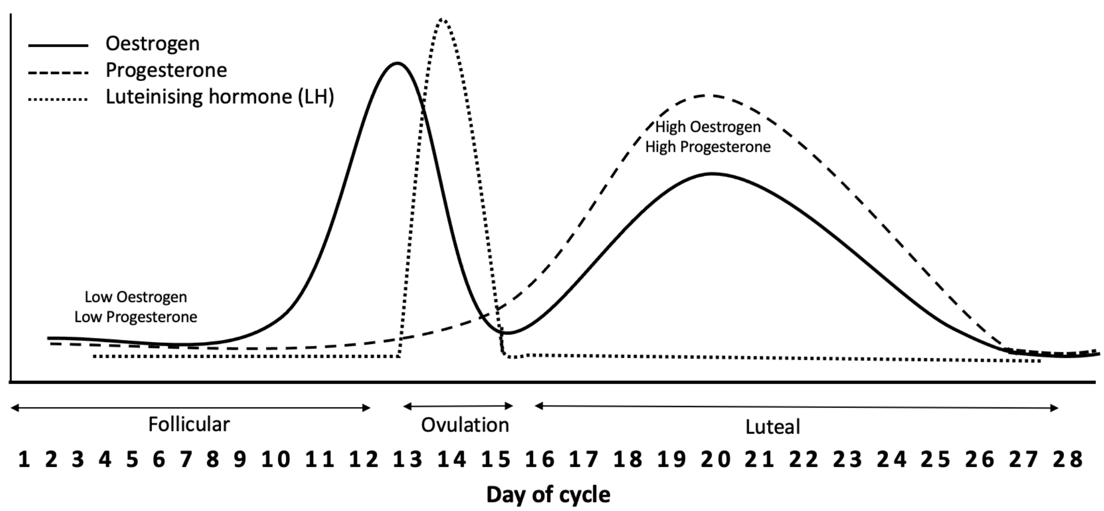


Figure 2: 28-day menstrual cycle (MC) with detailed phases with indicative hormone levels. Adapted from McNulty et al. (2020)

As represented in Figure 2, the FP occurs from day 1 of the MC to around day 14 based on a 28-day cycle; however, the length may vary from 21 to >35 days

(Marsh et al., 2002; Bull et al., 2019). The FP can be split into three sub-phases, early, mid, and late FP. The early FP is where menses occur, also known as the period and includes the shedding of the uterus lining (endometrium), so a bleed occurs. During menses, both oestrogen and progesterone are low, resulting in MC symptoms including but not limited to stomach cramps, mood changes, headaches, and tender breasts (Redman et al., 2004). The primary purpose of oestrogen during the MC is to grow the endometrial layer of the uterus (Marsh et al., 2002). Therefore, oestrogen subsequently increases through the mid FP, yielding the greatest concentration during the late FP, whilst progesterone concentrations maintain low throughout.

The OP, also known as ovulation, is the point that defines a regular cycle. A surge in the LH identifies this and determining this point can aid the accuracy of MC tracking by defining a precise point in the cycle (Janse de Jonge et al., 2019; McNulty et al., 2020). The OP breaks up the FP and LP and occurs when an egg is released from the ovary, an organ within the female reproductive system (Frankovich & Lebrun, 2000). Oestrogen is usually high at this point in the cycle, which results in a surge in the LH from the pituitary gland, thus releasing the egg (Frankovich et al., 2000).

As highlighted in Figure 2, the LP is the last phase of the cycle, which occurs from ovulation to the last day prior to menses of the next cycle. The typical length of the LP is 12 to 14 days; however, this can vary. The LP has three subphases, the early, mid, and late LP. The primary hormone within this phase is progesterone, which is stimulated by the LH surge during ovulation (Marsh et al., 2002). The mid-LP yields the greatest concentration of progesterone and the second-highest point of oestrogen. This will prepare the endometrium for potential fertilisation (Carmichael et al., 2021b).

2.3 Identification methods of the menstrual cycle (MC) phase

The methods used to identify and determine the MC phase are essential for the quality of research (McNulty et al., 2020). Poorly designed methods for monitoring the MC phase can lead to inaccuracies in identifying the correct phase and consequently to unreliable results (McNulty et al., 2020). It is challenging to create meaningful comparisons between studies due to significant differences in training status, protocol, and the number of participants across all studies. There are many approaches for confirming the MC phase and Table 1 below summarises methods applied by different studies. The combined use of calendar-based counting, urinary ovulation testing, and blood analysis was recognised in new methodological guidelines as the most accurate method to identify the menstrual phase in laboratory research (Janse de Jonge et al., 2019; Elliott-Sale et al., 2020).

Table 1: Methods used to determine MC phase

Study	**Methods Used**
Baker et al. (2004)	Calendar-based counting & BBT & urine
Oosthuyse et al. (2005)	Blood samples, BBT & urine
Rael et al. (2021)	Blood samples, calendar-based counting & urinary
Abdollahpor et al. (2013)	Blood samples & calendar-based counting
Cascazza et al. (2002), Friden et al. (2003), Tsampoukos et al. (2010)	Blood samples & urine
Freemas et al. (2020)	Saliva, BBT & urine
Ziomkiewicz et al. (2012)	Saliva & calendar-based counting
Wiecek et al. (2016)	Blood samples & BBT
Dean et al. (2003)	Calendar-based counting & urine
Middleton et al. (2006), Vaiksaar et al. (2011), Janse de Jonge et al. (2012), Julian et al. (2017), Azari et al. (2019), Grant et al. (2020), Dasa et al. (2021)	Blood samples only
Romans et al. (2015), Kose et al. (2018), Otaka et al. (2018), García-Pinillos et al. (2021)	Calendar-based counting only
Romero-Moraleda et al. (2019)	Urine only
Pallavi et al. (2017)	Did not state

Basal body temperature; BBT

Calendar-based counting is one of the most common indirect methods to determine the MC phase. This method assumes that females have a consistent 'normal' cycle. However, cycle and phase length can vary, where the FP tends to fluctuate more than the LP (Bull et al., 2019). It is more common for female athletes to experience MC irregularities due to intense training schedules compared to non-athletic females (De Souza, 2003). Therefore, calendar-based counting should not be used in isolation (Janse de Jonge et al., 2019).

Urinary LH measurement can identify ovulation (Janse de Jonge, 2003, Montgomery & Shultz, 2010; Bambaeichi et al., 2014) and is considered the least invasive and inexpensive direct method of identifying hormone fluctuations within the MC (Janse de Jonge et al., 2019). Identifying the surge in LH increases the accuracy of determining the point of ovulation. Urinary ovulation strips have shown a high accuracy (97%) rating (Su et al., 2017) however, false positives are not uncommon in predictor kits (McGovern et al., 2004). Moreover, Roos et al. (2015) stated that urinary hormone measurement aligned with blood serum hormones and the methods could be used interchangeably to monitor the MC reliably. Serum hormone measurement is the recommended approach to determine the MC phase (Janse de Jonge et al., 2019; Elliott-Sale et al., 2020). This method is invasive as a venous blood sample is required to detect serum oestrogen and progesterone levels (Janse de Jonge et al., 2019). A rise of progesterone in the LP is established to verify ovulation, with concentrations of >16 nmol·L^{-1} (Janse de Jonge et al., 2019). Therefore, as advocated by Janse de Jonge et al. (2019), urinary ovulation testing is an accurate method for determining ovulation in women with a regular MC and is an accessible and easy method for athletes when blood serum measurement isn't available.

Salivary hormone measurement is another non-invasive method, which measures oestradiol and progesterone in the saliva (Gandara & Leresche, 2007; Janse de Jonge et al., 2019). However, salivary hormones present with a much lower concentration and show larger variations compared to serum hormones

(Chatterton et al., 2005; Janse de Jonge et al., 2019). Therefore, when testing salivary hormones, tests with a high sensitivity and multiple measurements will need to be taken to provide the most accurate results (Gandara et al., 2007, Janse de Jonge et al., 2019).

Basal body temperature (BBT) refers to the lowest body temperature recorded, and females commonly observe a rise in BBT of around 0.4ºC during the LP (Driver et al., 1996; Shechter et al., 2010). Current recommendations advise females to measure BBT at the same time each morning before eating and drinking as this can influence results (Steward & Raja, 2020). Additionally, lifestyle factors such as stress, training schedules, illness, medication, alcohol, and sleep may influence BBT (Barron & Fehring, 2005; Janse de Jonge et al., 2019). BBT tracking is convenient but does not directly measure hormone concentrations and should be used alongside other methods such as blood serum and urinary LH measurements (Janse de Jonge et al., 2019). Overall, there are several identification methods available for athletes and although serum blood measurement is the most accurate measure, it is an expensive and invasive method (Janse de Jonge et al., 2019), thus not realistic for athletes over a long-time frame. Therefore, the combination of BBT, urinary ovulation testing and calendar-based counting provides an accessible and easy method for athletes to track their MC. However, no method should be used in isolation.

2.4 Menstrual cycle (MC) hormones and performance

Oestrogen and progesterone have been proposed to have a myriad of effects on many physiological systems including but not limited to metabolic, cardiovascular and respiratory (McNulty et al., 2020). All of which may have an influence on performance during various exercise modes. Mountain biking and cycling disciplines range from bouts of short-term high-intensity exercise to prolonged endurance exercise (Impellizzeri et al., 2007), therefore it is important to address the potential role oestrogen and progesterone have on female cyclists' performance.

Oestrogen has been proposed to have an influence on energy metabolism and be advantageous to short-term high-intensity exercise by favouring glucose uptake into type 1 muscle fibres and enhancing carbohydrate utilisation (Hackney, 1999; Oosthuyse et al., 2005). In addition, high oestrogen levels can be accompanied by lower blood lactate levels as the reliance on anaerobic pathways for ATP production decreases due to the rise in oxidative capacity. In turn, this benefits submaximal endurance exercise by increasing free fatty acid availability to use as a fuel source and lowering the respiratory exchange ratio (RER), leading to glycogen sparing (Oosthuyse & Bosch, 2012; Hackney et al., 2022).

Progesterone has presented anti-oestrogenic effects on metabolism by reducing glucose uptake and oxidation, beneficial for endurance performance (McNulty et al., 2020). However, progesterone has been shown to alter the thermoregulatory set point, increasing body temperature (Frankovich et al., 2000; Janse de Jonge, 2003; Charkoudian et al., 2016). This rise in body temperature may increase the subjective feeling of a greater strain or exertion during exercise and this may be specifically enhanced when exercising or competing in hot or humid environments (Janse de Jonge et al., 2012). In addition, the rise in body temperature has been proposed to impose a larger cardiovascular strain, leading to a negative effect on endurance performance (Charkoudian et al., 2016). A larger cardiovascular strain is associated with an increase in physiological responses such as HR, rate of perceived exertion (RPE) and volume of oxygen uptake (VO_2) (Janse de Jonge, 2003). Previous research has reported conflicting evidence on the above physiological responses between the MC phases, therefore further evidence will be discussed throughout the review.

It appears that FP may be favourable to cyclists completing short-term high-intensity exercise where the reliance on carbohydrates is essential and during the LP, a greater reliance may improve endurance performance on fat as a fuel source (Hackney, 1999; Oosthuyse et al., 2005; Hackney et al., 2022). However, the addition of a thermoregulatory strain may skew this effect and potentially lead to a negative impact on performance (Janse de Jonge, 2003 Charkoudian et al., 2016). Overall, a greater understanding of the mechanisms of sex hormones for short-term and endurance exercise in elite mountain bike, road and cyclocross athletes is required.

2.5 Physiological responses and the menstrual cycle (MC)

2.5.1 Body temperature

Daily body temperature fluctuates by up to 1ºC across a 24-hour period (Drust et al., 2005) and for females, another temperature rhythm occurs due to the MC. Progesterone is known to increase body temperature and during the LP, levels of progesterone rise, followed by an increased body temperature of ~ 0.4ºC (Driver et al., 1996; Shechter et al., 2010). Figure 3 illustrates the change in body temperature across a 28-day MC. Carmichael et al. (2021a) proposed that short-duration exercise requiring speed and power may benefit from the increased temperature in the LP as a result of improved muscle contractility and force production. This may be notable for mountain bike athletes requiring a high speed and power output during a race (Gregory, Johns & Walls, 2007). However, Somboonwong et al. (2015) highlighted that a proper warm-up before exercise during the FP might lead to no differences between the phases and further evidence is required. During prolonged exercise, a rise in resting body temperature may influence cooling mechanisms and increase heat stress during sustained exercise (Marsh et al., 2012). Janse de Jonge et al. (2012) observed a significant ($P<0.05$) increase in resting body temperature during the LP in active females (FP, 37.2 ± 0.1 ºC, and LP, 37.4 ± 0.3 ºC). During prolonged exercise in hot and humid environments, exercise time to fatigue was significantly ($P<0.05$) increased during the FP by 5.7% compared to the FP. However, the authors detected no change during exercise in temperate climates. Further research is required to determine if a rise in body temperature during the MC is critical for performance in elite female athletes. Specifically, in cyclists or during prolonged exercise in more challenging environments.

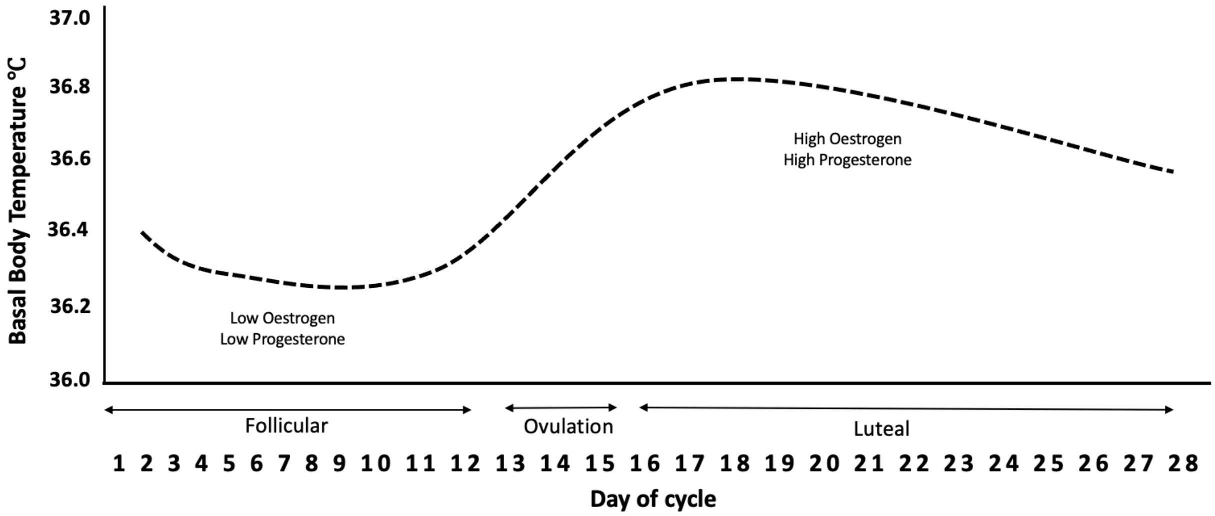


Figure 3: 28-day menstrual cycle (MC) with change in basal body temperature (BBT) across the cycle. Adapted from Baker et al. (2020)

2.5.2 Body mass

Similar to body temperature, body mass fluctuates over a 24-hour period and is influenced by daily habits such as eating, drinking, exercising, and sleeping. For females, fluctuations in hormones across the MC can also affect body mass (Stachoń, 2016). Previous research (Rael et al., 2021) has suggested that an increase in progesterone may lead to greater water retention during the LP. Specific to cyclists, body mass and body composition are critical in hill dominated disciplines such as XC, mountain and enduro. This results in an improved power to weight ratio, which may prove to be an advantage for uphill climbs (Impellizzeri et al., 2007). Therefore, too significant a rise in body mass could negatively affect power to weight ratio and, consequently performance (Impellizzeri et al., 2007).

Most researchers have observed no change in body mass across the MC for active females (Casazza et al., 2002; Middleton et al., 2006; Tsampoukos et al., 2010; Rael et al., 2021) and well-trained females (Julian et al., 2017). However, 40 well-trained female soccer, basketball, handball, and volleyball athletes were divided into two groups based on their subcutaneous fatness index (SFI) (less fat; <23.2 and more fat; >23.2). Both groups obtained a significant ($p>0.05$) increase in body mass during the LP by 0.42 and 0.53 kg, respectively (Stachoń, 2016). The athletes with a slimmer build or more hydrated status had a greater increase in body mass during the LP. The findings indicate that along with other factors such as increased consumption or reduced physical activity levels, athlete body build may be a factor that influences the rate at which body mass changes across the MC. However, a greater understanding of this process and why it occurs is required for further research. In addition, although Strachoń and authors detected a significant change in a well-trained athletic group, no research could be located on elite athletes. Therefore, there is a need for future research to measure body mass across the MC, specifically in cycling disciplines, where body mass is a crucial factor in performance.

2.5.3 Heart rate (HR) and training load

HR is a measurement used during exercise to establish exercise intensity and cardiovascular fitness. Previously, HR has been detected to rise significantly during the LP, characterised by increased progesterone concentrations in healthy females (Pivarnik et al., 1992; Seebauer et al., 2002; Janse de Jonge et al., 2012). Proposed mechanisms included decreased plasma volume and increased body temperature (Pivarnik et al., 1992), which augments cardiovascular strain. However, most research has detected no change in maximal HR response across the MC in recreational and active females (Dean et al., 2003; Oosthuyse et al., 2005; Abdollahpor et al., 2013). In response to athlete-based research, Julian et al. (2017) observed that 9 trained soccer athletes presented a significantly higher ($p<0.05$) pre-exercise HR during the LP (105 ± 12 bpm) compared to the FP (97 ± 16 bpm). Again, no change in HR_{max} was detected. Furthermore, in 21 endurance-trained females, exercising HR was significantly higher during the LP than the FP during an interval running protocol (8x3min bouts at 85% peak VO2) (Rael et al., 2021). From the findings highlighted above, there is not enough evidence to indicate that hormonal fluctuation across the MC influences HR during rest and exercise and there is limited evidence in elite female athletes. Therefore, more research is required to monitor HR responses across the MC in well-trained and elite athletes.

Training load is another method to measure exercise intensity and volumes of an athlete's training schedule (Halson et al., 2014). Training impulse models using HR can be applied to monitor training load and may include Banister's TRIMP (bTRIMP), Edwards' training impulse (EdTRIMP), individualised training impulse (iTRIMP) and Lucia's training impulse (LuTRIMP). Training volumes in female athletes are lacking, specifically in elite mountain bikers. Previously, Saunders et al. (2017) detected that although females spend less time training than their male counterparts, females spend more time training at a higher training load (5.72 ±

1.23 AU) relative to males (4.58 ± 1.75 AU). To date, there is no research defining the influence of the MC on the daily training load of an athlete (Cristina-Souza et al., 2019). Previously, coaches have been shown to reduce athletes' training load when experiencing symptoms associated with the MC required (Cristina-Souza et al., 2019). However, there is no evidence to state that a reduction in training load is required (Cristina-Souza et al., 2019).

However, training load may influence an athlete's MC or perceived stress level. If athletes endure high training loads, adequate energy intake is required to fuel training and optimise recovery. Otherwise, MC irregularities or a complete halt in the MC can occur, also referred to as relative energy deficiency in sport (RED-S) (Logue et al., 2018; Pitchers & Elliot-Sale., 2019). This in turn, can influence other factors such as musculoskeletal health, mood, decision making, susceptibility to illness and thus influence training and performance (Logue et al., 2018; Pitchers et al., 2019; Logue et al., 2020). Therefore, training load is important to monitor in athletes to ensure MC regularity, lower perceived stress, and reduce the risk of illness.

2.6 Sleep, the menstrual cycle (MC) and performance

Sleep is crucial for general health and wellbeing, specifically for athletic populations (Halson, 2014). Optimal sleep duration and quality is the best physiological and psychological recovery strategy to maximise performance for elite athletes (Halson, 2014; Simpson et al., 2017). Although the recommended sleep time is 7 to 9 hours for the average adult (aged 18-65), athletes should be achieving 9 to 10 hours per night (Halson, 2014; Hirshkowitz et al., 2015). This is to promote athletes' overall health and recovery around their intense training schedules (Simpson et al., 2017; Vitale et al., 2019). The circadian rhythm is a 24-hour cycle that controls sleep patterns and influences body temperature, hormone fluctuations, eating, digestion and the sleep-wake cycle (Thun et al., 2015). During sleep, the body rotates through four different stages; stages 1 to 3 are non-rapid eye movement (NREM), and stage 4 is rapid eye movement (REM) (Halson, 2014). On average, the body will move through the stages up to 4 to 6 times. As sleep time progresses, less time is spent in the NREM stages and subsequently more time in REM (Patel et al., 2020). REM sleep takes up around 25% of overall sleep and refers to the deepest point of sleep, where a lot of psychological activity occurs (dreaming). Sleep stages 3 to 4 are essential for brain function and cognitive performance (Carskadon & Dement, 2005; Copenhaver & Diamond, 2017). In turn, this is important for mountain bike, road and cyclocross athletes, where decision-making is a key performance indicator (Novak et al., 2017). Table 2 presents sleep stages and lengths in the general population. However, there is limited research on whether sleep stages and lengths differ in elite female athletes (Sargent et al., 2021).

Table 2: Sleep stages and length of each stage

Stage of sleep	Type of sleep	Normal length (minutes)
Stage 1	NREM	1-5
Stage 2	NREM	10-60
Stage 3	NREM	20-40
Stage 4	REM	10-60

REM; rapid eye movement, NREM; non-rapid eye movement

Although optimal sleep quality and duration are essential for elite athletes, previous research has detected poorer sleep measures in elite athletes compared to non-athletic cohorts. Leeder et al. (2012) compared sleep quality and duration in 46 elite athletes from four Olympic sports (rowing, diving, canoeing and speed skating) and 20 non-athletic participants, both male (N= 23) and female (N= 43). The athletic group presented a significantly reduced sleep efficiency (80.6 ± 6.4 %) compared to the non-athletic group (87.6 ± 3.6 %). Nonetheless, females presented a significantly improved sleep efficiency (83.9 ± 6.4 %) than males (81.5 ± 7.4 %) regardless of males spending more time in bed across all of the sports. Similarly, female athletes from the Brazilian Olympic team (pentathlon, gymnastics, canoeing, swimming, track and field, judo, volleyball and sailing) had a significantly greater sleep efficiency than the males (Silva et al., 2019). The MC was not accounted for in the above studies, and although Baker and Driver (2004) and Romans et al. (2015) reported a significantly ($p<0.05$) poorer perceived sleep quality during the LP for 26 and 76 non-athlete females respectively, no study has investigated the influence of sleep on the MC in elite athletes.

2.7 Psychological responses and the menstrual cycle (MC)

2.7.1 Alertness and arousal

Alertness is a state of continued attention and the ability to react quickly to a stimulus, whereas arousal is a psychological state of alertness that readies the body for action (Arent & Launders, 2003). Alertness and arousal are essential for optimal cycling performance when decision making, and a fast reaction time is critical throughout a race. This is specifically important in mountain biking in order to successfully ride a technical, fast-paced trail with many obstacles (Novak et al., 2017; Pomportes et al., 2021). An athlete can possess an optimal amount of arousal, and too much or too little can lead to a negative effect, known as the 'inverted U theory' (Arent et al., 2003).

The influence of the MC on arousal and alertness is undetermined, specifically in female athletes. Wright and Badia (2002) investigated the relationship between sleep, body temperature and alertness. Fourteen (3 female, 11 male) healthy participants underwent a battery of neurobehavioral tests every 2 hours. This included a neurobehavioral performance assessment to measure subjective alertness and attention through a visual analogue scale (VAS) and a 10 minute auditory psychomotor vigilance task (aPVT). The participants were required to respond to a random noise every 3 to 7 seconds, and a mean reaction time was calculated. The MC was not accounted for during the study but did determine a significantly improved alertness when body temperature was higher. A more recent study by Grant et al. (2020) investigated the relationship between cognitive performance and body temperature across the MC in 16 healthy females. Similar tests to Wright et al. (2002) were carried out to measure subjective alertness, and the authors observed improved neurobehavioral performance during the LP. It is apparent from the above findings that there is a relationship between body temperature and improved alertness in the general population. However, more research is required to determine if hormonal fluctuations across the MC may influence arousal and alertness in female athletic populations.

2.7.2 Perception of the menstrual cycle (MC) and associated symptoms

MC symptoms can range from minor to severe and may include but are not limited to stomach cramps, headaches, mood changes and fatigue. Compared to the FP, up to 90% of females have an increased negative mood state during the final days before and during menses (Ziomkiewicz et al., 2012; Freemas et al., 2020). A larger-scale study by Bruinvels et al. (2020a) observed that in 6812 recreationally active females, mood changes, increased anxiety, increased tiredness, and fatigue were the most reported symptoms. It has been proposed that exercise can also alleviate symptoms due to improved circulation to the uterus or by a subsequent rise in endorphins during exercise (Kishali et al., 2006). In addition, during competition, athletes reported that they did not experience any MC symptoms or perceived negative effects during performance (Slade et al., 2009; Findlay et al., 2020) and it is postulated to result from greater arousal and attention placed on the competition. However, during training sessions in familiar environments, the same females suffered from many symptoms such as abdominal pains and cramps, leading to a perceived negative effect on performance, potentially influencing training negatively.

Ergin et al. (2020) revealed that in a cohort of 130 elite female volleyball athletes, 84.6% of individuals experienced symptoms during menses. 70.8% reported that training and competition were influenced by menses but did not state why. In addition, within a group of 15 international rugby players, 93% experienced MC symptoms, and 67% believed these symptoms to impair their performance. Finally, in a cohort of elite cross-country skiers and biathletes, 71% of athletes perceived their quality of training to be negatively affected during menses. However, 50% of the athletes perceived their performance to improve during the FP and LP (Solli et al., 2020). Therefore, it is evident that athletes experience the greatest perceived reduction in performance in the lead up to and during menses when symptoms arise. Nevertheless, the severity of symptoms and the perception of performance will vary between individuals and the environment. Both athletes and coaches must track the athlete's MC and manage symptoms around training and performance.

2.8 Menstrual cycle (MC) and anaerobic performance

Achieving high intensity, intermittent sprints are required for many elite cyclists across all disciplines (Maciejczyk et al., 2015). A significantly greater sprint performance during the LP was detected in 6 active females who completed 10 x 6 second cycling sprints (Middleton et al., 2006). Conversely, in trained athletes, research has detected no change in anaerobic performance between phases of the MC (Julian et al., 2017; García-Pinillos et al., 2021; Rael et al., 2021). There was no significant change ($p>0.05$) in repeated sprint performance (Julian et al., 2017; Rael et al., 2021) or an all-out 30 second sprint (García-Pinillos et al., 2021). This could be a consequence of training status and the variety of different athletes and sports within the research. However, anaerobic performance in well-trained and elite cyclists has not been documented and greater research is required. Nevertheless, the findings agree that the MC does not influence exercise with a duration of 3 minutes or less in trained females. This may be prevalent for DH riders when a race lasts up to 3 minutes. However, riders will complete multiple runs during training and access more than just the anaerobic system. In fact, during a race, cyclists will need to access the whole continuum of the energy system and therefore studying the influence of the MC on anaerobic performance in isolation may be problematic. Measuring performance across all energy systems could be conducted to better understand how the MC influences the realistic demands of a mountain biker or road cyclist. Therefore, more research is required to determine the impact of the MC on anaerobic performance after numerous sprints in elite athletes.

2.9 Menstrual cycle (MC) and aerobic performance

Endurance performance is considered to improve during the FP when oestrogen levels are high and progesterone is low (Oosthuyse & Bosch, 2010). During the LP, the presence of an increased thermoregulatory response may increase cardiovascular strain and reduce endurance performance (Oosthuyse et al., 2010). However, current research investigating endurance performance in female cyclists is limited. No significant differences ($p>0.05$) in continuous endurance performance during a 15 and 30 km cycling time trial (Oosthuyse et al., 2005) or cycling test to exhaustion (Smekal et al., 2007) was observed in active females. Similarly, 9 competitive rowers' aerobic performance did not alter across the MC phases during a rowing test to exhaustion (Vaiksaar et al., 2011). However, Julian et al. (2017) did observe an improved incremental endurance performance with a greater distance covered in the FP (3289 ± 801 m) compared to the LP (2822 ± 896 m) during a yo-yo intermittent endurance test to exhaustion. In addition to the conflicting results across the various training statuses (rowing, cycling, football), all of the research was conducted in relatively short duration exercise (<1 hour). However, for mountain bikers and road cyclists, performance can occur over several hours and the effect of the MC in short duration aerobic performance may not apply to much longer efforts. Therefore, further research is required to determine the impact of the MC on prolonged endurance exercise in elite athletes.

2.10 Menstrual cycle (MC) and muscular strength

Within cycling, strength plays a vital role across all disciplines. One aspect of strength essential for cycling is grip strength. Greater grip strength will improve performance for riders, allowing them to travel faster on challenging trails whilst maintaining control (Chidley et al., 2015). Further, isometric handgrip exercises have been correlated with changes in cardiac output, HR and blood pressure (Burr et al., 2012). Pallavi et al. (2017) investigated muscle strength in 100 young females (18-24 years) who performed exercise 1 to 2 times per week. The females' handgrip strength was significantly greater ($p<0.001$) during the FP (33.04 ± 3.7 kg) compared to the LP (27.3 ± 3.4 kg). However, no other studies observed a change in other strength measures across the MC (Kose et al., 2018; Romero-Moraleda et al., 2019; Azari et al., 2019; Dasa et al., 2021). Both Kose et al. (2018) and Azari et al. (2019) detected no significant difference in bench press between MC phases for 10 kickbox athletes (Kose et al., 2018) and 20 recreationally trained females (Azari et al., 2019). In addition, half squat (Romero-Moraleda et al., 2019) and leg press (Azari et al., 2019) did not change. The wide variety of muscle groups and training levels mentioned above indicates that the MC may only influence certain muscle groups; however, further research is required to confirm this. An apparent gap in the literature can be detected, as no studies measuring strength across the MC in elite cyclists exists and future research is required.

2.11 Conclusion

Research investigating the influence of the MC on highly trained and elite populations is limited, and most of the studies have investigated a wide variety of sporting disciplines in untrained and active females. This of course is important however, there is a growing need for more attention in elite sports. There is very little evidence on training and performance measures in elite mountain bikers and road cyclists and there is no research investigating the effect of MC on training and performance measures in this cohort. Notably, the rise in body temperature in the LP is associated with increased arousal and alertness, leading to improved performance and a rise in HR and other physiological measures, which could decrease performance. Due to the mixed populations and abundance of low-quality research as a result of poor methods for MC determination and small sample sizes, current findings are mixed, and no sound conclusion can be drawn. This review has allowed for a greater understanding of what research is missing and why more focus is required for female mountain bikers and road cyclists at an elite level. With equal UCI races for male and female cyclists in 2021, no previous research has yet investigated the influence of the MC in elite female mountain bike, road and cyclocross cyclists.

2.12 Project aim and objectives

This study will aim to determine if different phases of the MC influences training schedules, sleep quality, arousal and alertness in female mountain bike, road and cyclocross athletes. This study will be the first of its kind and add to the growing body of research, helping to build upon the specific guidelines for female athletes. It is hypothesised that 1) BBT, body mass, arousal and alertness will increase during the LP, 2) sleep quality and sleep length will decrease during the LP and 3) average HR, training load and RPE will increase during the LP. The research will ask the following questions: Will BBT and body mass alter between the FP and LP? Will perceived sleep quality, sleep length, and arousal or alertness alter between the FP and LP? Will training load, HR and RPE alter between the FP and LP? Will COVID-19 influence MC characteristics in well-trained and elite female mountain bike, road and cyclocross athletes?

Chapter 3: Methods

3.1 Participant characteristics

Fifteen female well-trained (N= 7) and elite (N= 8) cyclists with a regular MC participated in the study. Females were aged 18 to 45 years, injury-free and were not using any hormonal contraceptives in the last 6 months (Casazza et al., 2004). Athletes had competed at a minimum of national level in the last 2 years for road cycling, cyclocross or in at least one mountain bike discipline (XC, DH, enduro and marathon). From training history, athletes were deemed well-trained (>8-15 hrs and >3 days per week) and elite (>17 hrs and >5 days per week) (Decroix et al., 2016; McKay et al., 2022). For participant breakdown of disciplines, refer to Table 3.

Table 3: Baseline participant characteristics split by discipline

	Enduro (N= 6)	XC (N= 3)	DH (N= 1)	Cyclocross (N= 1)	Road (N= 3)	Marathon (N=1)	Group Average (N=15)
Age (y)	29 ± 7.5	28 ± 9.3	26 ± 0	43 ± 0	26 ± 7.1	37 ± 0	29 ± 7.4
Height (m)	1.6 ± 0.1	1.7 ± 0.1	1.7 ± 0	1.6 ± 0	1.7 ± 0.1	1.8 ± 0	1.7 ± 0.1
Body mass (kg)	66.4 ± 5.6	62.8 ± 8.1	60 ± 0	48.8 ± 0	56.6 ± 6.7	63 ± 0	61.9 ± 7.7
Body max Index (BMI) kg/m^2	24.6 ± 1.9	21.5 ± 1.7	21.3 ± 0	19.5 ± 0	20.3 ± 1.0	20.1 ± 0	22.5 ± 2.6
Chronotype	60.7 ± 7.2	58.7 ± 7.2	48 ± 0	63 ± 0	44.2 ± 8.1	49 ± 0	55.8 ±8 .9

Mean ± standard deviation (SD), Cross country; XC, downhill; DH

3.2 Study design

This observational study followed a cohort of female cyclists over three months, tracking MC symptoms, training and competition data, self-reported sleep quality, and psychological factors such as arousal and alertness. Participants were recruited using online posts on social media platforms (Twitter, Facebook, Instagram, LinkedIn) or through contact of cycling groups and teams worldwide. The athletes performed their normal training and competition routine, and no intervention occurred. All athletes provided information from their training and competition data, acquired using their individually preferred GPS system (Garmin Connect, Polar, Strava, Training Peaks, Wahoo). The schematic design of the study is illustrated in Figure 4. Participants provided full written consent (Appendix 6), and ethical approval for this study was granted by Edinburgh Napier University.

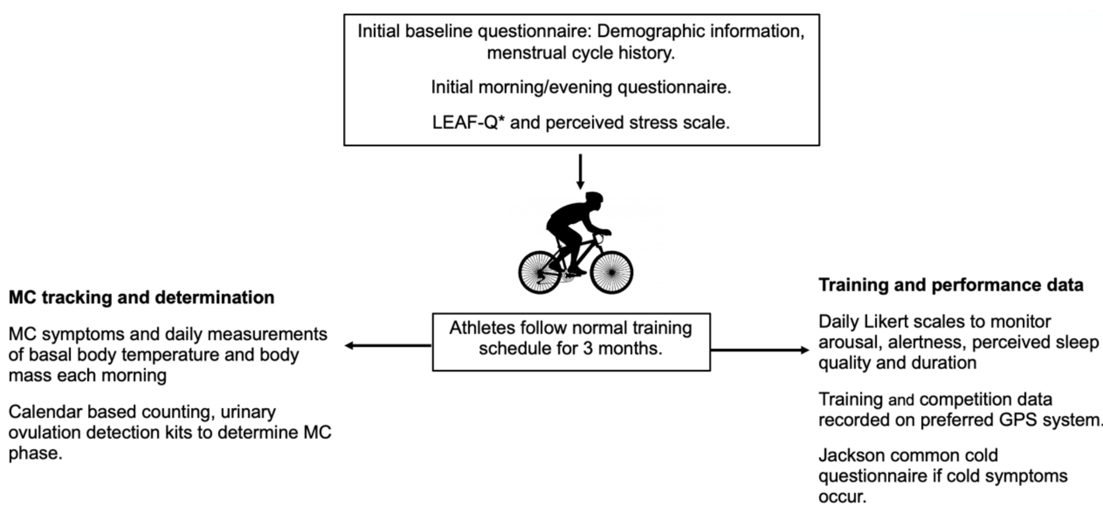


Figure 4: Schematic design of study

3.3 Pre-screening

Participants were required to undergo a pre-screening process by completing a number of questionnaires using Qualtrics survey software (Qualtrics, Provo, UT). Firstly, a perceived stress scale (Cohen et al., 1983; Appendix 5) indicated how naturally stressful the athlete's life was, as stress plays a big part in hormone imbalances and may influence the MC (Harlow, & Matanoski, 1991). Athletes rated 10 questions with the following scale: 0 - never 1 - almost never 2 - sometimes 3 - fairly often 4 - very often. The total score indicated low (<13), moderate (14-26) and high stress (27-40). A morning/evening questionnaire (Horne & Östberg; Appendix 6) is a self-assessment questionnaire that better indicated the athlete's sleep-wake habits and identified their chronotype. Chronotype was grouped by definite morning (score 70-86), moderate morning (score 59-69), intermediate (score 42-58), moderate evening (score 31-41) and definite evening (score <30).

A low energy availability in female's questionnaire (LEAF-Q) measured RED-s (Melin et al., 2014; Appendix 7) due to energy availability being a large factor in MC function. A score ≥8 indicates that the athlete is at risk for low energy availability and female athlete triad (Melin et al., 2014). Demographic information including age, height, body mass, age of menarche, competitive level, length of time competing at current level and weekly training volume was recorded (Appendix 8). To determine MC regularity, participants provided their menstruation start dates and lengths for the previous three months (Schaumberg et al., 2017). Age range did not exceed 45 years to account for when perimenopause is likely to start (Worsley et al., 2012). Finally, if cold or flu symptoms developed, participants were required to complete a Jackson common cold questionnaire daily until symptoms passed (Barrett et al., 2005; Appendix 9).

Once the pre-screening questionnaire was completed, the researcher excluded 11 participants who did not meet the inclusion and exclusion criteria of the study. The inclusion criteria included a regular MC, aged 18-45, train ≥4 days per week, compete nationally or internationally in the last 2 years. The exclusion criteria included any hormonal contraceptive taken in the last 6 months prior to starting the study and had an injury in the last 6 months prior to starting the study.

3.4 Menstrual Cycle Tracking

Participants were provided with a MC tracking sheet on a shared drive (SharePoint) to track each day of their MC. Each phase of the MC was determined by identifying the point of ovulation for each participant; the FP (onset of menses to before ovulation) and LP (post ovulation). To determine the point of ovulation, participants were sent a LH ovulation predictor strips (Ovulation test strips, 20mlIU/mL kit tests, width 2.5mm, One Step; 99% accuracy). From the previous 3 months of MC information provided (Schaumberg et al., 2017), average cycle length was calculated and the day to begin ovulation testing was determined from the table provided by the manufacturer (Home Health (UK), Ovulation Test Strips 20mIU/mL Tests 3.5mm Wide One Step, 10 Tests; Appendix 12). From this day, participants were required to collect a urine sample to test for the surge in LH, until a positive result was observed. Participants were initially sent 15 strips (5 per cycle) however, extra strips were provided if necessary. The day to begin testing typically occurred 3 days prior to predicted ovulation to ensure ovulation was not missed. If a positive result was not obtained a fourth cycle of data collection was completed (Schaumberg et al., 2017).

Participants started the study on day one of their MC (first day of bleeding) and marked an ‘X’ against any symptom experienced on the MC tracking diary. Symptoms included but were not limited to abdominal pain, tiredness, tender breasts, fatigue, and back pain. In addition, participants were provided with an oral thermometer (Basal Digital Ovulation Thermometer (Celsius), One Step) to measure BBT daily. Following packet instructions, athletes measured BBT upon wakening and before getting out of bed, as standing up will influence BBT (Baker et al., 2020). Athletes were requested to take the temperature at the same time each morning between the hours of 6 am and 8 am, based on wake time. Daily self-reported body mass measurements in kg were also required each morning, at the same time each day (between 6 am and 8 am) prior to voiding the bladder. Body mass scales were not provided, and all participants used the same personal scale each day. Results for both BBT and body mass were recorded in the MC tracking diary.

3.5 Riders’ training

All athletes provided access to training and competition data, including non-cycling data such as strength training, running, and swimming. Athletes received a daily checklist and weekly reminders to provide the previous week’s training and competition files. Data including HR, duration of training, distance covered, elevation gain, and speed were uploaded from the athletes preferred GPS tracking system (Strava, Garmin, Polar) to an individual folder on SharePoint (Microsoft, 2022). The data was then uploaded to Golden Cheetah (http://www.goldencheetah.org/) by the researcher. Athletes also recorded their RPE using the Borg scale (Borg, 1982) for each session.

During the three months, athletes completed daily Likert style questions upon wakening to monitor arousal, alertness, and perceived sleep quality and duration (Appendix 10). Arousal was measured on a 1 to 7 scale, with 1 being ‘feeling active, vital, alert and awake to 7 being ‘almost in reverie, sleep onset soon, lost struggle to remain awake’ (Hoddes et al., 1973). Alertness was measured on a Likert scale of 0 to 10, where a mark to the extreme left indicates ‘as tried as I’ve ever felt’, the extreme right indicates ‘as alert as I’ve ever felt’. Similarly, perceived sleep duration was measured on a Likert scale of 0 to 10. A mark to the extreme left indicates sleep quality as ‘very bad’, and extreme right indicates sleep quality as ‘excellent’. Perceived sleep duration was determined as the predicted number of hours of sleep the participant attained. Numbers from the corresponding scales were inserted into the MC tracking diary.

Training load was calculated using Banisters TRIMP model (bTRIMP) (Banister, 1991), calculated from the data collected from the athletes. Due to the remote nature of this study, the bTRIMP model was selected. However, it is recognised that due to the intermittent nature of a mountain bike session, some key data may be missed when averaging the HR. bTRIMP was calculated based on training duration, HR, and a weighting factor using the following formula:

$$bTRIMP = time\ (minutes) \times \Delta HR \times 0.86^{1.6x}$$

Where:

$\Delta HR = (HR_{ex} - HR_{rest}) / (HR_{max} - HR_{rest})$e equals the base of the Napierian logarithms, 0.86 equals a generic constant for females. HR_{ex} = exercising heart rate, recorded as one average value every 5 s, HR_{rest} = resting heart rate, and HR_{max} = maximum heart rate. To obtain resting heart rate (HR_{rest}), athletes were requested to rest supine for 5 minutes wearing a HR strap and record their results. The lowest 5 second HR was recorded as their HR_{rest}. If participants knew HR_{max} from previous laboratory testing, this HR_{max} was used. Otherwise, a peak heart rate from a training session was considered HR_{max}. However, if this was not known, a calculation was used by applying the following formula to estimate HR_{max}; 216 – 1.09 × age (Whyte et al., 2008).

3.6 Post study questionnaire

After completing the study, participants attended a virtual interview to answer open ended questions on any impact the COVID-19 pandemic had on their training and race schedules, as well as any change in their MC during the pandemic (Appendix 11).

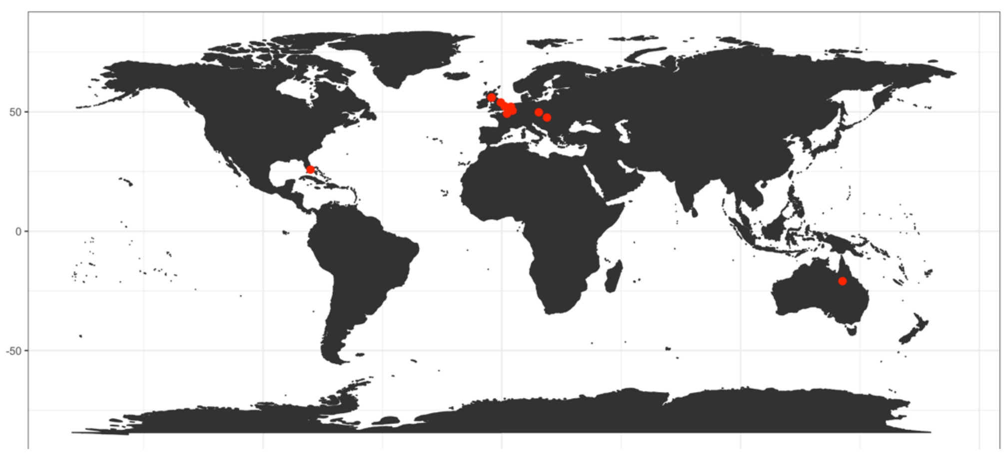
3.7 Data Analysis

All data analysis was performed using R (R Core Team, 2020) in RStudio (Rstudio Team, 2020). All MC data was stored in CSV, all training data was stored in Golden Cheetah (http://www.goldencheetah.org/), and bTRIMP was calculated in Golden Cheetah. If participants dropped out their data was not included in the analysis and an intention to treat analysis was not included. All data was checked for normality, Levene's tests for the equality of variances were all non-significant (P>0.05), normality assumption was not violated, and equal variances were assumed. A repeated measures analysis of variance (ANOVA) assessed the effect of MC (BBT, body mass, sleep length) and training variables (HR, distance, speed, elevation gain, bTRIMP), during the study by identifying a menstrual cycle phase (phase) versus menstrual cycle (cycle) interaction effect (phase; FP/LP x cycle; 1/2/3). In addition, an ANOVA identified effects of phase across training status (status) (phase; FP/LP x status; well-trained/elite). The magnitude of effect was reported using Cohen's *d*, where 0.2, 0.5 and >0.8 represent small, medium and large effects, respectively (Cohen, 1992). To examine statistical differences for Likert-Scales between phases for each of the cycles, the non-parametric Friedman test was used (p<0.05). Followed up with the Wilcoxon (two-tailed) T-test (p<0.05) to identify statistically significant differences between phases at each cycle.

Chapter 4: Results

4.1 Participant characteristics

A wide range of ethnicities were included within the study and participant characteristics and breakdown of disciplines are presented in Table 3. Participants specialised in various mountain bike and cycling disciplines including enduro, DH, XC, marathon, road and cyclocross. The athlete group were considered heterogenous as athletes body composition (height, weight, BMI) varied for different requirements of the disciplines, as well as the inclusion of different training levels (well-trained and elite). Furthermore, all participants were the same ethnicity (white) and the group presented with a range of nationalities, (Figure 5).



Characteristic	N = 15[1]
Nationality	
Australian	1 (6.7%)
Brazilian	1 (6.7%)
British	9 (60%)
Canadian	1 (6.7%)
Czech	1 (6.7%)
European	1 (6.7%)
Hungarian	1 (6.7%)

[1] n (%)

Figure 5: Map of participant location and percentage (%) number of participants for each nationality

From the pre-screening information, the athlete's perceived stress score was compared between the well-trained (N=7) and elite (N=8) athletes. There was no significant difference ($t(9)= 0.2$, $p= 0.98$) in perceived stress between well-trained

(13 ± 4) and elite (13 ± 8) athletes. The mean score indicated a low perceived stress for both groups. In addition, the mean score from the LEAF-Q was not significantly different ($t(9)=0.4$, $p=0.79$) between the well-trained (3 ± 2) and elite (4 ± 3) athletes and indicated a low risk of low energy availability.

4.2 The menstrual cycle (MC)

MC characteristics for the participant group are presented in Table 5 below. No significant differences were observed between all 3 recorded cycles (bleed length; $F(1, 35)= 2.29$, $p= 0.14$, cycle length; $F(1, 36)= 0.10$, $p= 0.80$, phase length; $F(1, 4)= 0.1$, $p= 0.75$). Age of menarche and number of bleeds per year are also presented in Table 4.

Table 4: MC length and breakdown for participant group (N= 15)

Variable	Mean ± SD	Range
Full Cycle (days)	26 ± 3.8	21-34
Bleed length (days)	4.0 ± 0.9	3-6
FP (days)	13.0 ± 2.9	8-16
LP (days)	12.0 ± 2.1	10-17
Age of menarche (years)	13.0 ± 1.1	12-15
Number of bleeds per year	11.0 ± 1.3	8-12

Age of menarche; age when MC started, FP; follicular phase, LP; luteal phase

Figure 6 presents the percentage of reported symptoms for all participants for each cycle. There was no significant ($p>0.05$) main effect of cycle between the

MC symptoms (abdominal pains; $F(1, 70)= 1.38$, $p= 0.24$, back pain; $F(1, 70)= 0.40$, $p= 0.53$, bloating/increased gas; $F(1, 70)= 0.30$, $p= 0.59$, diarrhoea; $F(1, 70)= 1.77$, $p= 0.59$, headache/migraines; $F(1, 70)= 1.41$, $p= 0.24$, mood changes; $F(1, 70)= 0.23$, $p= 0.63$, stomach cramps; $F(1, 70)= 0.01$, $p= 0.92$, tender breasts; $F(1, 70)= 0.34$, $p= 0.56$, tiredness/fatigue; $F(1, 70)= 2.23$, $p = 0.14$). Two participants reported missing a race due to the severity of abdominal pains and stomach cramps. No athletes reported upper respiratory tract infections or illness during the study.

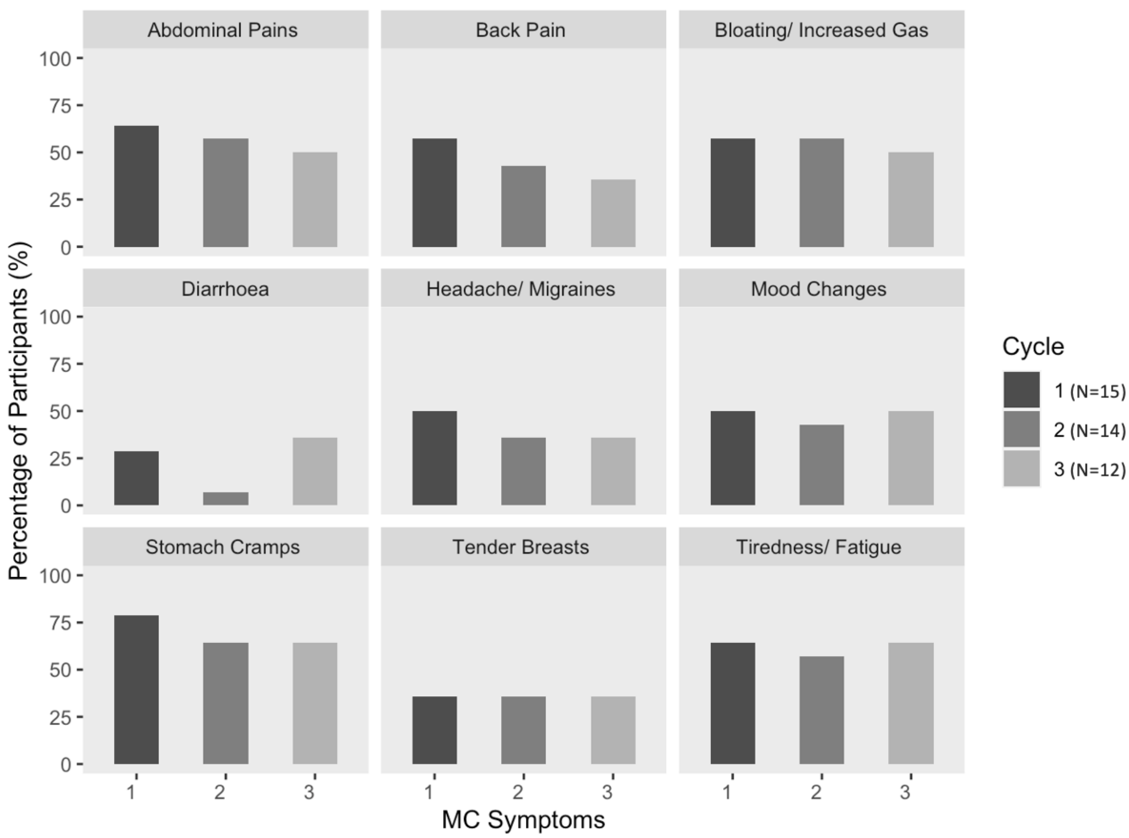


Figure 6: Total percentage of participants who reported symptoms during menses for each cycle

4.3 Basal body temperature (BBT) and body mass

There was no significant interaction (phase x cycle) in BBT (phase x cycle interaction; F(1, 11)=4.23, p=0.06, main effect of cycle; F(1, 11)= 0.89 p= 0.37). Mean BBT was significantly higher in the LP compared to the FP by 0.4, 0.4 and 0.3 ℃ for cycle 1, 2 and 3 (main effect of phase; F(1, 11)= 11.95, p= 0.01, d= 0.4, Table 5).

There was no significant interaction (phase x cycle) in body mass between the phases for each cycle (phase x cycle interaction; F(1, 12)=0.91, p=0.12, main effect of phase; F(1, 12) = 0.38, p= 0.54, d= 0.04, main effect of cycle; F(1, 12)= 3.21, p= 0.94, Table 5).

Table 5: BBT and body mass, phase x cycle interaction

Variable	Cycle 1		Cycle 2		Cycle 3	
	FP	LP	FP	LP	FP	LP
BBT (ºC) *	36.3 ± 0.5	36.7 ± 0.3	36.3 ± 0.3	36.7 ± 0.3	36.3 ± 0.9	36.6 ± 0.3
Body mass (kg)	62.2 ± 6.1	61.1 ± 6.1	61.9 ± 6.0	61.4 ± 7.0	61.2 ± 6.0	60.7 ± 6.9

Values presented as mean ± SD, significance, * for main effect of phase (p<0.05)

4.4 Arousal and alertness

There were no significant difference (p>0.05) between median arousal scores for any of the cycles (X^2 (5) = 5.346, p= 0.375). Further, there were no significant differences (p>0.05) for median arousal scores between the phases for each cycle (Cycle 1; Z= -2.00, p=0.46, Cycle 2; Z= -0.14, p=0.88, Cycle 3; Z= -0.68, p=0.50). Table 6 presents median with lower and upper quartile range values.

No significant difference ($p>0.05$) between median alertness scores for any of the phases in each cycle (X^2 (5) = 3.028, p= 0.696) was observed. Further, there were no significant difference ($p>0.05$) between median alertness scores between any the phases for each cycle (Cycle 1; Z= -2.00, p=0.46, Cycle 2; Z= -0.14, p=0.88, Cycle 3; Z= -0.68, p=0.50). Table 6 presents median with lower and upper quartile range.

Table 6: Arousal and alertness

Likert Variable	Cycle 1		Cycle 2		Cycle 3	
	FP	LP	FP	LP	FP	LP
Arousal	2.5 (2-5)	3.0 (2-5)	2.8 (1.8-5.3)	2.8 (2-6)	3.0 (2-2.3)	3.0 (1.8-5.3)
Alertness	6 (5.8-7)	7 (6.8)	6.5 (5.8-8.3)	7 (6-9)	7 (5.8-7.7)	6.8 (5.9-7.6)

Values presented as median (lower quartile and upper quartile range)

4.5 Sleep outcomes

No significant difference ($p>0.05$) between median perceived sleep quality scores for any of the phases in each cycle (X^2 (5) = 3.310, p= 0.652) was observed. Further, there were no significant difference ($p>0.05$) between median perceived sleep quality scores between any the phases for each cycle (Cycle 1; Z= -0.899, p=0.374, Cycle 2; Z= -0.689, p=0.491, Cycle 3; Z= -1.461, p=0.144).

No significant interaction (phase x cycle) in perceived sleep duration (phase x cycle interaction; $F(1, 12)= 0.03$, $p= 0.86$, main effect of phase; $F(1, 12)= 2.18$, $p= 0.17$, $d= 0.06$; main effect of cycle; $F(1, 12)= 0.15$, $p= 0.71$, Table 7).

Table 7: Perceived sleep quality and duration

Likert Variable	Cycle 1		Cycle 2		Cycle 3	
	FP	LP	FP	LP	FP	LP
Sleep quality	7 (7-7.5)	8 (7-8.5)	7 (7-8.3)	7 (7-8.5)	7 (6.6-7.5)	7 (7-8.5)
Sleep duration (hrs)	8 ± 1	8 ± 1	8 ± 1	8 ± 1	8 ± 1	8 ± 1

Values presented as median (lower quartile and upper quartile range) for sleep quality, mean ± SD for sleep duration

From the athlete group, a mean morning/evening (M/E) score was 56 ± 9. One athlete was a definite morning type, six were moderate morning, eight were intermediate types and one was a moderate evening type. There was no significant interaction (phase x cycle) for sleep quality (phase x chronotype interaction; $F(3, 15)=1.90$, $p= 0.17$, main effect of phase; $F(3, 15)= 2.36$, $p= 0.61$, $d= 0.42$, main effect of chronotype; $F(3, 15)= 1.98$, $p= 0.09$). There was no significant interaction for perceived sleep duration (phase x chronotype interaction $F(3, 15)= 2.93$, $p=0.11$, main effect of phase; $F(3, 15)= 0.24$, $p= 0.00$, $d= 4.1$, main effect of chronotype; $F(3, 15)= 2.93$, $p= 0.11$).

4.6 Training outcomes

The total volume of training for the whole group in each cycle is presented in Table 8. A total 1,588 hours of training from 815 sessions across all training modes were collected over 3 months. There were no significant interaction (phase x cycle) for any of the training variables (phase x cycle interaction for total hours training; $F(1, 38) = 0.03$, $p = 0.10$ total distance covered; $F(1, 38)=0.02$, $p = 0.10$ bike; $F(1, 38)=0.01$, $p = 0.07$ strength training; $F(1,38) = -0.31$, $p = 0.93$ races; $F(1, 38)= 2.0$, $p = 0.17$ other; $F(1, 38)= 0.10$, $p = 0.12$).

Table 8: Group total training hours, distance and mode collected for each cycle and phase of the study

Variable	Cycle 1 (N=15)		Cycle 2 (N=14)		Cycle 3 (N=12)		Total	p-value
	F	L	F	L	F	L		
Training								
Distance on bike (km)	302	304	242	277	235	229	302	0.10
Time spent training (hrs)	4706	4229	3081	3999	2741	3620	22376	0.10
Training mode								
Bike	112	98	87	101	70	86	554	0.07
Strength training	23	30	17	19	26	25	140	0.93
Races	5	20	12	8	6	3	54	0.17
Other	11	18	17	16	11	5	78	0.12

Other activities include running, walking, and swimming. F; follicular phase, L; luteal phase

The average weekly training time, distance covered, and elevation gain for all sessions, as well as the average number of weekly sessions for bike, strength training (ST) and other sessions are presented in Table 9. No elevation data was provided from participant 13. Weekly training was ordered by discipline and grouped means were calculated. On average, road cyclists covered the most distance (217 km), whilst obtaining a lower elevation gain (883m), compared to XC with the largest elevation gain (3806m) followed by enduro (2174m), marathon (2074m), DH (1904m) and cyclocross (960m) athletes. Further, on average, elite (E) spent more hours training vs well trained (WT) (17 ± 4 hrs vs 11 ± 5 hrs), covered more distance, (173 ± 117 km vs 107 ± 61 km) and a greater elevation gain (2724 ± 1945 m vs 1575 ± 645 m).

Table 9: Weekly training for each discipline and number of sessions per week (N=14)

Discipline	Time recording (hrs)	Distance covered on bike (km)	Elevation gain (m)	Bike sessions	ST sessions	Other sessions
Enduro	13 ± 5	124 ± 42	1975 ± 1196	3 ± 2	1 ± 1	2 ± 1
XC	16 ± 5	179 ± 71	3720 ± 2010	5 ± 2	1 ± 1	0
Road	13 ± 4	217 ± 110	883 ± 385	4 ± 2	2 ± 1	1 ± 1
DH	14 ± 4	-	1904 ± 744	2 ±1	3 ± 1	2 ± 1
Cyclocross	10 ± 3	126 ± 69	960 ± 680	5 ± 4	0	0
Marathon	16 ± 6	313 ± 121	2074 ± 1302	4 ± 2	0	1 ± 1

Mean ± SD, ST; strength training, other sessions; running, swimming, walking, training, '- '; no data provided.

Total training load was determined via bTRIMP and was grouped by training status in Figure 7 below. There was no significant interaction (phase x status) for total bTRIMP (phase x status interaction; F(1, 20)= 0.19, p=0.66, main effect of phase; F(1,20)= 0.12, p= 0.74, d=2.5, main effect of status; F(1,20)= 9.33, p= 0.01). In addition, there was no significant interaction (phase x discipline) for total bTRIMP (phase x discipline interaction; F(4, 14) = 0.14, p = 0.96, main effect of phase; F(1, 14)= 0.10, p=0.77; main effect for discipline; F(4, 14) = 2.07, p=0.14). Participants 12 and 13 were removed from Figure 7, as bTRIMP data was not collected and 11 and 31 were removed as they did not provide training data for cycle 3.

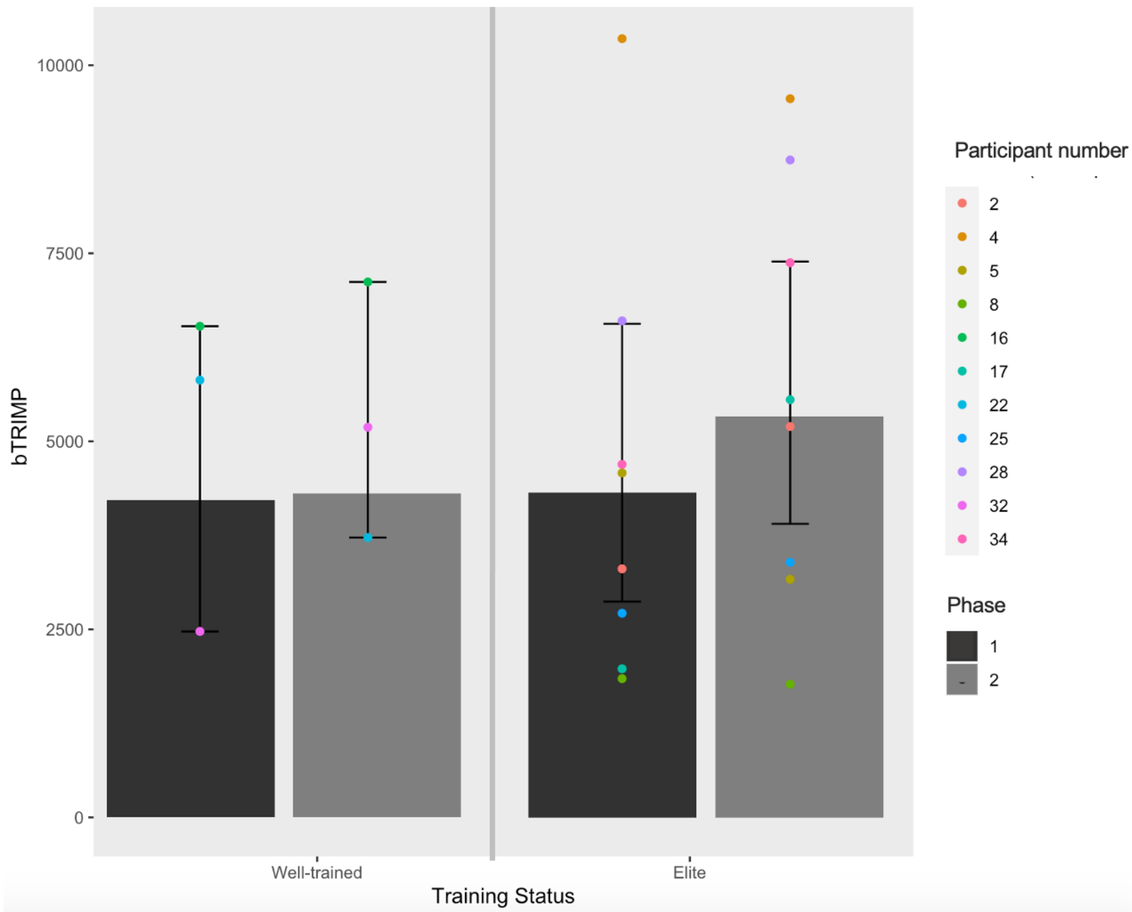


Figure 7: Mean total training load (bTRIMP) across each phase, split by training status, individual total bTRIMP values for each participant presented.

In Table 10, no significant interaction (phase x status) was observed for average HR (F(1, 24) = 0.26, p= 0.87, d= 9.39), maximum HR (F(1, 24)= 0.01, p= 0.92, d= 9.59), average speed (F(1, 24)= 0.01, p= 0.92, d= 3.63), maximum speed (F(1, 24)= 1.79, p= 0.19, d= 7.57), bTRIMP (F(1, 12)= 1.93, p= 0.18, d= 3.59) and RPE (F(1, 24)= 0.22, p= 0.88, d= 12.74). There were no significant difference between the phases for the combined group for average HR (F(1, 12) = 1.13, p= 0.30, d= 9.64), maximum HR (F(1, 12)= 0.22, p= 0.64, d= 4.50), average speed (F(1, 12)= 0.01, p= 0.98, d= 2.80), maximum speed (F(1, 14)= 0.47, p= 0.49, d= 4.12), bTRIMP (F(1, 12)= 0.08, p= 1.29, d= 3.78) and RPE (F(1, 14)= 0.10, p= 0.77, d= 13.01).

Table 10: Training variables for phase (FP/LP) x status (well-trained/elite) interaction, and combined group results

Variables	Well-trained (N=7)		Elite (N=8)		Group mean (N=15)	
	FP	LP	FP	LP	FP	LP
Average HR (bpm)	133 ± 34	130 ± 41	123 ± 39	125 ± 34	128 ± 37	128 ± 38
Maximum HR (bpm)	166 ± 36	159 ± 50	156 ± 56	158 ± 51	155 ± 49	154 ± 51
Average speed (km.hr)	20.6 ± 20.7	19.2 ± 8.8	19.2 ± 8.7	20.3 ± 9.2	20.3 ± 15.6	19.8 ± 9.0
Maximum speed (km.hr)	41.5 ± 19.5	41.6 ± 16.5	48.4 ± 24.4	44.1 ± 18.5	45.1 ± 22.4	42.8 ± 17.5
RPE	13.7 ± 2.7	13.6 ± 3.2	12.8 ± 2.7	13.2 ± 2.8	13.2 ± 2.7	13.4 ± 3.0
bTRIMP (A.U.)	154 ± 150.3	210.8 ± 196.6	191 ± 145.4	167.5 ± 98.8	173.5 ± 148.6	189.8 ± 158.3

Values presented as mean ± SD, A.U; arbitrary unit

4.5 Impact of COVID-19 content analysis

The findings of the post-study interview (N = 10) are presented below. For each question, the categories produced, sample quotes and frequency of responses for each category is presented in each Table below.

For the influence of COVID-19 on training schedules (Table 11), responses under the category ‘learn new skills’ was the most frequently cited positive outcome. This refers to athletes allocating more time to focus on developing new skills as training load decreased due to race cancellations. ‘More time’ was another commonly cited outcome for positive impact on training schedules. This refers to athletes having more time to relax and spend time focusing on family or other priorities. Quotes have been provided in Table 11. Furthermore, responses under the category ‘no structure/routine’ was the most frequent negative outcome. This refers to athletes struggling with lack of routine and nothing to work towards as races were cancelled. This category was more commonly cited than the categories generated from the positive impact. Quotes have been provided in Table 11.

Table 11: *Content analysis relating to COVID-19' influence on training schedules*

Question	Categories generated	Description	Quotes	Frequency
Positive impact on training schedules	More time	Reference to additional time available to relax and focus on other priorities as a result of reduced commitment to the sport	*“I had more time to take a break and spend some more quality time with family”*	6
	Learn new skills	Reference to learn or develop new skills or hobbies as there was more time due to no races	*“I took up a few different disciplines of bike riding. Like enduro and jumps riding, which is really fun, and I think it's good for my skills, so that's something I'll keep doing.”*	7

Negative impact on training schedules	No structure/routine	Reference to athletes struggling with no routine or structure as all races had been cancelled with nothing to work towards	*“I was doing a lot of unstructured training as there were no competitions to work towards”*	9
	No access to training facilities or locations	Reference to closure of facilities and the inability to travel	*“I didn’t have access to any local woods, and travelling would break covid guidelines so I spent more time focussing on running"*	4

Key: Frequency = number of responses categorised

For the influence of COVID-19 on racing schedules (Table 12), responses under the category ‘races bunched together’ was the most frequently cited outcome on the impact COVID-19 had on racing schedules. This refers to races being scheduled closer together to get as many races as possible back on the calendar, allowing for minimum time for recovery between events. Quotes have been provided in Table 12. How athlete’s felt towards racing during COVID-19 had the most frequent responses under the category ‘felt safe racing’. This refers to the social distance and sanitation measures put in place at races.

Table 12: Content analysis relating to COVID-19 influence on racing schedules

Question	Categories generated	Description	Quotes	Frequency
Impact on racing schedules	Races bunched together	Reference to more races being scheduled closer together to account for cancellations previously	*“I would usually race 30+ a season but the majority were cancelled and then the most important ones were all bunched together into a really short time period and it was hard to maintain”*	3
	Travel/accessibility	Reference to some COVID-19 restrictions in certain countries made it challenging to travel	*"It was different in how far we have to travel and accessibility to races, usually I would have races less than 1 hour away, but all of the races were further away. The different tier systems in the UK made it even more challenging.”*	2
	More challenging to enter races	Reference to more individuals entering the races and with number restrictions it made it more challenging to enter	*"I found it hard to enter a lot of the races as more people were taking part and there was a larger restriction on the number of entries due to social distancing"*	2
Feelings towards racing during COVID-19	Felt safe racing	Reference to the precaution’s organisers put in place to make athletes feel safe at races	*“During travelling to races abroad, I felt safe due to all the precautions in place”.*	7

	No spectators	Reference to the removal of spectators for some of the races during the pandemic	*"Having no spectators was also really hard and missing the social side of it, wearing masks on podiums and presentations felt tough."*	3

Key: Frequency = number of responses categorised

For the influence of COVID-19 on the MC (Table 13), responses under the category 'no change' was the most frequently cited outcome on the impact COVID-19 had on the MC. This refers to athletes observing no change in their MC characteristics over the lockdown period. Less frequent responses included 'more regular' which referred to athletes observing their MC to become more regular, 'less symptoms experienced' where athletes reported that they experienced less MC related symptoms. Finally, 'change in cycle length' which referred to athletes experiencing a longer or shorter cycle length.

Table 13: Content analysis relating to COVID-19' influence on the menstrual cycle (MC)

Question	Categories generated	Description	Quotes	Frequency
Impact on the menstrual cycle	More regular	Reference to athlete's reporting their MC to be more consistent and regular	*"During lockdown my period became more regular, and I knew when It was coming every month, that never occurred before"*	2
	Less symptoms experienced	Reference to athlete's experiencing less severe or frequent symptoms during menstruation	*"I experienced less severe symptoms during lockdown, specifically less stomach cramps/pain"*	2
	Change in cycle length	Reference to athlete's reporting their MC to change in length	*"I experienced change in the length (couple days shorter) of my period 2020 April to June. Maybe because of different training approach or not getting enough movement and as it was a strict lockdown at that time."* *"Ever since April my cycle it is significant longer and now lasts around 40 days but before covid it wasn't that long*	2
	No change	Reference to athlete's observing no change in their MC	*"I noticed no change in my menstrual cycle."*	5

Key: Frequency = number of responses categorised

Chapter 5: Discussion

5.1 Key findings

This current study aimed to determine if different phases of the MC influenced training schedules, sleep quality and alertness or arousal in female mountain bike, road and cyclocross athletes. It was firstly hypothesised that physiological and perceptual measures including BBT, body mass, arousal and alertness would significantly increase in the LP. Although BBT increased significantly during the LP, compared to the FP, the first hypothesis is rejected as body mass, arousal and alertness did not alter significantly between the phases ($p>0.05$). It was secondly hypothesised that perceived sleep quality and duration would significantly increase during the FP however, there was no significant difference ($p>0.05$) between the phases, rejecting the second hypothesis. The third hypothesis was that training measures (average HR, bTRIMP, RPE) would significantly improve during the FP however, there was no significant difference between the phases ($p>0.05$), rejecting the third hypothesis. In addition, a large effect size was detected between the phases, and thus a larger sample size may have increased the significance of results. Finally, COVID-19 influenced the athlete's training schedules both positively and negatively and the most frequent response to COVID-19's influence on MC characteristics was no change.

5.2 The menstrual cycle (MC)

The group means for MC characteristics are summarised in Table 5. On average, the cycle length for the athletes was 26.0 ± 3.8 days, FP length was 13.0 ± 2.9 days, and LP length was 12.0 ± 2.1 days. Differences in cycle length are usually due to greater variation in the FP (Mihm, Gangooly, & Muttukrishna, 2011) and the phase lengths ranged between 8 to 16 days. Previously, a large-scale study collected 600,000 MC's from 124,648 females within the general population (Bull et al., 2019). A similar trend was observed to the current study indicating a longer FP length (16.9 ± 5.3 days) compared to the LP (12.4 ± 2.4 days). To the author's knowledge, no research on MC lengths has previously been conducted in well-trained or elite cyclists however, Carmichael et al. (2019b) and Findlay et al. (2019) have observed similar cycle lengths to the current study in elite football (28 ± 3 days) and rugby (28 ± 5 days) athletes. Therefore, from the current findings and previous research presented (Bull et al., 2019; Carmichael et al., 2019b; Findlay et al., 2019), it is suggested that well-trained and elite athletes have similar MC lengths and characteristics compared to their non-athletic counterparts.

Age is another factor that may influence cycle length and why variation might have occurred between the athletes. Naturally, as females get older, MC length will decrease (Bull et al., 2019). It is essential to highlight that the age of the athletes ranged from 21 to 43 years, but due to the pre-screening questionnaire, no females within the group highlighted any MC cycle irregularities associated with perimenopause. This refers to the point where changes in the MC occur before menopause and begin at around age 45 years (Worsley et al., 2012). The findings so far demonstrate that MC characteristics for well-trained and elite female athletes do not differ from the general population and non-athletic females.

However, no research could be located to determine if menopausal age varies in elite athletes.

MC symptoms were analysed during the days of menses when athletes were bleeding. The average bleed length was 4.0 ± 0.8 days, with a range of 3-6 days. Symptoms including tiredness and fatigue, bloating and increased gas, abdominal pains and stomach cramps were reported by the greatest percentage of participants (Figure 6). Likewise, Brunivels et al. (2021) observed that tiredness and fatigue and stomach cramps were also the most prevalent symptoms in 6812 females who exercised regularly. Similar symptoms were also reported in elite athletes (Findlay et al., 2019; Armour et al., 2020). Therefore, it is apparent that both athletes and the general populations also experience similar MC symptoms.

Additionally, it is important to highlight from the present study and previous research on athletes that the prevalence and severity of symptoms can also vary in the length and the number of symptoms experienced (Findlay et al., 2019; Armour et al., 2020). In fact, in the current study, two participants reported missing a race due to the severity of their stomach cramps and abdominal pains. Thus, individual variation is present in the athlete cohort, and athletes can perceive their performance to reduce during menses when experiencing MC symptoms (Carmichael et al., 2021a). The present study adds to the growing body of research as the first study to investigate the prevalence of MC symptoms in well-trained and elite female cyclists. It is therefore recommended that coaches and athletes should monitor MC symptoms to manage training expectations during menses.

Illness from the Jackson common cold survey reported no upper respiratory symptoms from any of the athletes during the study. It was expected that the athletes would have experienced some symptoms during the study however, the COVID-19 pandemic has increased protective measures against disease. Examples include a decline in travel, improved hand hygiene, face masks, social distancing, and reduced spectators at sporting events and competitions (Toresdahl, & Asif, 2020). Therefore, this may lead to lower transmission of respiratory infections for athletes. The additional stressor of exercise can increase susceptibility to illness (Malm, 2006) however, the influence of the MC on upper respiratory tract infections in elite female athletes is considered unclear (Yasuda et al., 2013; Castanier et al., 2021). Oestrogen is considered to be immune enhancing, consequently leading to greater levels of salivary IgA, which in turn protects against pathogens entering the body and reduces the risk of illness (He et al., 2014; Castanier et al., 2021). Previously, studies have detected no significant difference in upper respiratory tract infections between the FP and LP in well-trained female endurance runners (Burrows et al., 2002SHe et al., 2014). Therefore, further longitudinal research is required in elite female athletes to determine if there is a greater susceptibility to upper respiratory tract symptoms in certain MC phases, which may consequently lead to performance decrements.

5.3 Basal body temperature (BBT)

Average BBT increased significantly during the LP by 0.4, 0.4 and 0.3 ºC for each cycle, indicating a consistent increase in BBT even when daily fluctuations in body temperature are present. The current findings agree with previous research (Driver et al., 1996; Shechter et al., 2010; Händel et al., 2019) however, studies researching the influence of BBT across the MC on exercise performance are limited. A rise in body temperature increases cardiovascular strain and perceived exertion which will lead to a quicker onset of fatigue, specifically during prolonged exercise (Maughan & Shirreffs, 2004). However, well-trained and elite females have been recognised to possess the desirable thermoregulatory response, such as enhanced sweating, to combat the rise in body temperature (Heathcote et al., 2018). Baker et al. (2020) suggested that well-trained and elite athletes are less likely to experience changes in performance across the MC however, there is very little evidence to confirm this (Sunderland et al., 2002; Oosthuyse et al., 2005; Garcia et al., 2006; Smekal et al., 2007; Janse de Jonge et al. 2012).

Previously, in active females, Janse de Jonge et al. (2012) detected a negative effect on endurance performance during the LP in hot and humid environments however, Garcia et al. (2006) and Sunderland and Nevill (2003) observed no change in submaximal cycling performance ($p>0.05$) or intermittent sprints ($p>0.05$) during the MC, respectively. Additionally, in temperate environments, BBT has not been shown to influence aerobic performance during a 15 and 30 km time trial on a bike (Oosthuyse et al., 2005), cycle test to exhaustion (Smekal et al., 2007) or a submaximal cycle (Garcia et al., 2006) in active females.

Consequently, from the current study and previous findings presented above (Garcia et al., 2006; Janse de Jonge et al., 2012), body temperature increases by 0.3-0.5 ºC during the LP at well-trained and elite levels. The current study could not directly measure performance between the FP and LP however, the previous research highlighted has indicated that there is no apparent influence on submaximal and maximal aerobic performance due to a rise in body temperature in the LP during temperate environments for active females. In addition, exercise in hot and humid environments may indicate some negative effects on endurance performance (Janse de Jonge et al., 2012) however, research investigating the effect of an increased BBT on performance in elite female athletes could not be located. This is the first study to measure BBT across the MC for well-trained and elite mountain bike, road or cyclocross athletes and a greater understanding on the effect of BBT on cycling performance is required in elite athletes.

5.4 Body mass

From participant characteristics (Table 3), body mass was 61.9 ± 7.7 kg across the athlete group. When split by discipline, road and cyclocross athletes presented a lower body mass (56.6 and 48.8 kg) than the enduro, XC and marathon mountain bike athletes (66.4, 62.8 and 63 kg). However, it would be expected that the cyclists who specialised in uphill rides would obtain a lower body mass for improved power to weight ratio (Impellizzeri et al., 2008).

Impellizzeri et al. (2008) oppose the current findings where elite female mountain bikers presented a significantly lower body mass (53.7 ± 3.3 kg) than the cyclists specialising on level roads (58.0 ± 4.6 kg). Other factors that may have influenced the conflicting results were the present studies' poor discipline split, small participant size, and the inclusion of well-trained and elite cyclists. Although body mass did not differ between the well-trained and elite cyclists in the present study, Haakonssen et al. (2016) observed no change in body mass for female sub-elite (60.71 kg) and elite road cyclists (60.14 kg). In addition, well-trained female cyclists presented a similar body mass of 61 ± 7 kg (Lamberts and Davidowitz, 2014), parallel to the present study. However, Lamberts et al. (2014) did not state what cycling disciplines the riders specialised in and thus, body mass may present a larger variation to match different discipline requirements.

When determining differences between the phases of the MC, average body mass was not significantly different between the phases (Table 5). This was unexpected because it was hypothesised that body mass would increase during the LP in response to a rise in progesterone, increasing the hormone aldosterone and, thus fluid retention in female athletes (Szmuilowicz et al., 2006; Desbrow et al., 2019). However, the online nature of the study relied on athletes using their own scales which may have led to inaccurate readings. Nevertheless, previous studies have observed no change in body mass between the FP and LP in physically active (Middleton et al., 2006, Tsampoukos et al., 2010; Rael et al., 2021) and well-trained females (Julian et al., 2017). Stachoń (2016) indicated that females attaining a lower body fat (SFI <23.2) would observe smaller fluctuations in body mass compared to females with a higher body fat (SFI >23.2). However, further research is required to better understand the physiological responses to this change across the MC. Nevertheless, this is an important observation for cyclists who require a smaller body fat percentage to optimise performance (Stachoń, 2016). Although the current study did not measure body fat percentage, this could be an essential consideration for further studies. Overall, more research investigating body mass across the MC is imperative for athletes within disciplines such as mountain biking, road and cyclocross, where fluctuations in body mass could skew performance negatively.

5.5 Arousal and alertness

Psychological measures such as arousal and alertness may be critical for a cyclist's performance. When riders are faced with fast-paced, challenging routes, athletes must be alert for quick decision-making and reaction times (Pomportes et al., 2021). Across each cycle, there was no significant change in the median for perceived alertness or arousal scores between the FP and LP (Table 6). Research surrounding arousal or alertness and the MC is limited. As previously highlighted, an increase in BBT (0.4 ºC) has been associated with many parameters, including a rise in arousal, alertness and enhanced cognitive performance (Wright et al., 1999; Wright et al., 2002; Grant et al., 2020). It was expected that arousal and alertness would increase during the LP as a result of the significant (0.4 ºC, $p<0.05$) increase in BBT observed in the present study. However, the above studies were conducted in non-athletic populations, and sleep-deprived individuals and the findings from Wright et al. (1999) and Grant et al. (2020) may not be relevant to well-trained and elite athletes who may possess enhanced cognitive performance and the ability to control alertness and arousal prior to and during training or competition (Ludyga, Gronwald & Hottenrott, 2016; Mehrsafar et al., 2020). In addition, the current study used subjective Likert scales to measure perceived arousal and alertness. However, cognitive performance tests such as a VAS or aPVT may have been more accurate to measure arousal and alertness. Therefore, from the current findings, perceived arousal and alertness did not alter between the FP and LP and were subsequently not affected by the MC. Nevertheless, this is the first study to investigate perceived arousal and alertness across the MC in well-trained and elite female cyclists, and further research measuring cognitive performance is required.

5.6 Sleep outcomes

The recommended number of hours of sleep an athlete should achieve each night is 9 to 10 hours for optimal recovery and performance (Halson, 2014). Perceived sleep duration, on average, was 8 hours per night, which is less than the recommended sleep for athletes. Based on a scale of 1 to 10, perceived sleep quality, with 1 being the worst sleep and 10 being the best sleep, presented no significant differences between the phases. There were no significant differences between the FP and LP for perceived sleep quality or duration ($p>0.05$). Contradicting Carmichael et al. (2021b), 5 elite female Australian footballers attained a significantly poorer perceived sleep quality during the LP than the FP, which has been postulated as a potential consequence of a rising body temperature (Driver et al., 1996). The opposing results between the current study and Carmichael et al. (2021b) may be a result of many factors influencing sleep quality may include but not limited to training demands of the different sporting disciplines (cycling vs Australian football) such as training schedules and training load worldwide travel for competitions, chronotype or sleep environment (Halson et al., 2021). In addition, both studies were small-scale with a small sample size and research investigating sleep quality in well-trained and elite female athletes across the MC is sparse. There is sufficient evidence to indicate that elite athletes experience poorer sleep quality than the recommended sleep guidelines for athletes (Sargent et al., 2021). In a study of 479 elite athletes, 52% were considered poor sleepers on the Pittsburgh Sleep Quality Index (PSQI) (Halson et al., 2021). Furthermore, Sargent et al. (2021) observed that in a cohort of 175 elite athletes across a wide array of sporting disciplines, including mountain biking and road cycling, athletes on average required 8.3 hours a night to feel rested. However, they typically achieved 6.7 hours and 72% of athletes did not achieve the 8.3 hours. Therefore, is it important to be aware that there are many factors which can influence sleep however, from the current results and the limited research on the MC's effect on sleep quality and duration, more research is required to determine if the MC does have an impact on athletes sleep parameters at a well-trained and elite level.

In addition, athletes were grouped by chronotype to identify any influence on perceived sleep duration and quality. No significant differences in perceived sleep quality or length were observed between the participants when grouped by chronotype. Similarly, previous research in elite athletes has presented no significant differences in perceived sleep quality between different chronotypes (Lastella et al., 2016; Lastella et al., 2021). When grouped by chronotype, seven participants were definite or moderate morning types, eight intermediate and one evening type. This finding was expected as endurance athletes tend to present as a morning type to account for their training schedules, where training is likely to occur in the morning (Rae et al., 2015; Lastella et al., 2016). The DH athlete presented as an evening type and previous research has shown that evening types tend to perform better in the late afternoon or evening (Rae et al., 2015; Lastella et al., 2016). Although the DH athlete had power-based training sessions predominately in the afternoon or evening, they still require a strong aerobic base. There is not enough evidence in the present study to state that DH athletes are more likely to be evening types compared to other disciplines such as enduro and XC. More research investigating chronotypes across different cycling disciplines is required to determine if sleep quality or duration is influenced by chronotype or the MC in well-trained and elite athletes within the present study.

5.7 Training outcomes

Weekly training, irrespective of MC length or phase (Table 9), illustrates, on average, how much training the athletes were undertaking weekly. This was ordered by discipline to determine if there were different discipline requirements based on distance on the bike, elevation gain and different session types. As expected, road cyclists obtained the lowest elevation gain compared to the other disciplines, which are considered more hill dominant. The DH athlete covered the shortest distance per week as she had a greater number of strength training sessions, which is expected. However, a high aerobic capacity is essential for DH riders, as more focus is placed on technical ability, strength, and power (Chidley et al., 2015).

Training volumes in female well-trained and elite mountain bikers are lacking, and there are only a handful of studies based on female elite road cyclists (Van Erp et al., 2019; Barreto et al., 2021). Previously, females' daily duration and hours of training were 64.1 km and 2.4 hrs, respectively (Van Erp et al., 2020), and an average distance per session ranged between 39.2 to 81.8 km (Barreto et al., 2021). The present study analysed weekly training rather than daily training volumes and thus cannot be directly compared. Nevertheless, this is the first study to provide weekly training volumes over a competitive season, and future research is required to build normative data for well-trained and elite mountain bikers.

Athletes' training load was measured via bTRIMP to determine the frequency and intensity of the athletes' training (Saunders et al., 2017). Mean bTRIMP for the FP and LP was observed for each phase when grouped by training status (well-trained/elite, Table 10). No significant differences were observed between the phases, indicating that training variables did not differ regardless of training status. In addition, the total training load did not significantly change between the well-trained and elite athletes. Figure 7 did show extreme outliers between participants in the elite group, which could be driven by training level or discipline due to the different types of training between disciplines and the number of training sessions and competitions completed. Furthermore, athlete's used different GPS trackers to record their sessions which may have influenced the bTRIMP scores due to the reliability in the HR data collected. No research comparing the training loads for well-trained and elite female cyclists could be located however, from the current study it is observed that although well-trained athletes cover less distance and hours each week, their training load and intensity are similar to that of elite athletes. However, as previously highlighted there were extreme outliers which may have been driven by discipline, training level or data collection methods.

To date, no research has investigated bTRIMP in female well-trained and elite mountain bike and cycling disciplines. Previously, in male mountain bike and cycling disciplines, it has been proposed that bTRIMP may underestimate or overestimate certain disciplines (Kirkwood, 2019). In fact, bTRIMP scores were much lower in elite enduro males (Kirkwood, 2019) than elite road cyclists (Saunders et al., 2017). In addition, females have been shown to spend more time training at a higher training load (5.72 ± 1.23 AU) relative to their male (4.58 ± 1.75 AU) counterparts (Saunders et al., 2017). Overall, a better understanding of how the MC influences training load in well-trained and elite female mountain bike, road and cyclocross athletes is required.

Conversely, training load can influence the MC. During pre-screening, 10 out of the 15 athletes highlighted that they had experienced less or no bleeding when training intensity increased. However, no athletes observed this during the study and from the LEAF-Q questionnaire, no females were considered at risk of low energy availability as no athletes scored >8 (Melin et al., 2014). Nevertheless, if athletes undergo a high training load, adequate fuelling is required to maintain a regular MC. A lack of energy can result in an inconsistent or a complete stop in the MC (Logue et al., 2020). As previously highlighted, it has been recognised that up to 44% of athletes have reported MC disturbances, specifically in weight-dependent and endurance-based sports (De Souza, 2003).

In addition, a rise in training load may influence an athlete's perceived stress (Otter et al., 2016). Perceived stress score was measured during the pre-screening of the study based on "past month" feelings. There were no significant differences between well-trained and elite athletes, and both groups presented a low perceived stress score. Perceived stress was not measured at multiple points of the study, and the initial result could be influenced by training and lifestyle. There is limited research investigating perceived stress exclusively in female athletes and the additional influence of the MC. Previously, Vannuccini et al. (2020) detected a higher perceived stress score in 112 elite female athletes (17.3 ± 4.8) compared to 103 females who do not participate in sport (13.8 ± 4.8). However, no research could be detected in perceived stress scores for well-trained versus elite female athletes. Further identification is required to determine if different phases of the MC influence perceived stress in female well-trained and elite athletes.

HR is another physiological determinant of training intensity. When grouped by discipline, no significant differences in average HR or HR_{max} were observed between FP and LP or between cycles (Table 10). Further, training status did not influence HR values. Several studies have also detected no change in average or HR_{max} between the FP and LP in untrained and active (Lebrun et al. 1995; Abdollahpor et al., 201p3; Stone et al., 2020) or well-trained females (Julian et al., 2017). In a group of recreational and a group of elite rowers, HR at maximal load and threshold intensity did not change ($p>0.05$) between the FP and LP (Vaiksaar et al., 2011). No further research investigating the changes in average HR or HR_{max} during exercise across the MC in elite athletes could be identified. Therefore, this is a clear focus for future research using elite female populations. In addition, fluctuations in exercising body temperature have been proposed to influence HR (Pivarnik et al., 1990; Stone et al., 2020). Although exercising body temperature could not be measured, it was postulated that HR would rise in the LP in response to an increase in BBT. However, it is possible that the 0.3℃ rise in BBT was not large enough to influence exercising HR. Additionally, other factors which have affected the HR results were the different HR monitors used during the study: Garmin, Wahoo and Polar. Therefore, from the aforementioned results, HR does not appear to be influenced by the MC for recreational and well-trained, and research in elite athletes is required.

Furthermore, RPE was also measured to determine training intensity across the MC. Irrespective of training status, mean RPE did not significantly change between the FP and LP (Table 10). Similarly, previous research has detected no change in RPE between the FP and LP for well-trained and elite athletes (Julian et al., 2017; Carmichael et al., 2021b). This is the first study to measure RPE across the MC in well-trained/elite mountain bike, road or cyclocross athletes. Consequently, the results add to the literature, and the current findings display that RPE during exercise for well-trained and elite cyclists does not differ between the FP and LP.

The final training outcomes measured during the study were average and maximum speed (Table 10). The well-trained and elite athletes observed no significant differences in speed between the FP and LP. No previous research has investigated average and maximum speed in normal training schedules across the MC. Additionally, the training variables were not split by discipline because they were underpowered. However, it would be expected that enduro athletes would exhibit a lower average speed compared to the other disciplines. This results from enduro athletes' schedules, including many hill-focused sessions to account for the high aerobic power required during the competition (Kirkwood et al., 2017). MC and training status did not significantly influence any of the training variables discussed above during their normal individual schedules. Nevertheless, this is the first study to observe the influence of the MC in a normal training environment and provide a realistic picture of training for female well-trained and elite mountain bike, road and cyclocross athletes.

5.8 Impact of COVID-19

Sport across the world was decimated when the COVID-19 pandemic hit in 2020, with global sporting events such as Tokyo 2020 being postponed. Due to the unique time this study was conducted during the COVID-19 pandemic, a post-study interview allowed for a greater understanding of how COVID-19 may have affected athletes' training and race schedules and their MC.

All the interviewed participants stated that they experienced changes in their training schedules during the pandemic. The most frequent responses were categorised under “learn new skills”, due to races being cancelled at the start of the pandemic and the athlete’s used this time to focus on areas for development and build new skills which could be transferred into their 'normal' training and competition. Similarly, Bowes et al. (2020) evaluated the impact COVID-19 had on 95 elite sportswomen across various sports, including but not limited to netball, football and cricket. 76% of the athlete’s stated that their training volume decreased during the lockdown. Furthermore, the athlete’s highlighted a lack of access to facilities and equipment, which influenced their type of training.

When races resumed, and international travel opened up again, the athlete’s were asked how their schedules differed prior to the pandemic. All of the athlete’s noticed a change, including back-to-back races and finding it challenging to reach specific events based on travel restrictions. As observed in previous research (Bowes et al., 2020) and the current study, the reduction in training load during the pandemic may have led to some detraining (Sarto et al., 2020). Consequently, this had an effect on physiological systems, muscular strength, and led to a greater risk of injury or reduced performance, especially if there was a sudden increase in training load when racing schedules began (Sarto et al., 2020). The changes in athletes' racing schedules were highlighted but the effects of detraining on the athletes were not identified in the present study. To date, no research has investigated the transition from lockdown to racing in well-trained or elite female cyclists.

In addition, the athletes were asked how they felt racing during the pandemic and the most frequent responses were categorised were by "felt safe racing" as a result of the extra COVID-19 precautions put in place. Whilst other responses were categorised as "no spectators" as athletes found it challenging with less atmosphere or friends and family for support. Therefore, the influence of COVID-19 on athletes' feelings towards racing was individual but, 100% of the athlete's were glad to be back racing.

Moreover, the athlete's experienced a positive, negative (20%) or no change in their MC during the pandemic. Responses under the category "no change" were the most frequently reported. However, a small frequency of athlete's identified positive changes including a more regular cycle and athlete's stomach cramps and abdominal pains were less severe compared to before the pandemic. Negative responses included variations in their cycle length, both an increase and a decrease. Although 60% of the athletes within this present study were located in the United Kingdom, McNamara et al. (2020) observed that 24.7% of elite athletes in Australia experienced changes in the MC during the pandemic. Notably, a factor which may have influenced the findings of the current study was the widespread locations of the athletes. It has been recognised by Bruinvels et al. (2021b) that geographical location may be a key factor for MC changes, as many countries experienced different restrictions and numbers of fatalities. Bruinvels et al. (2021b) postulated that the MC changes could be greater in countries where COVID-19 restrictions were stricter, and deaths were greater.

Male (2021) detected that a change in the MC may result from an immune response to the vaccine instead of a vaccine component. Although participants were not asked if the COVID-19 vaccine impacted their MC, two participants reported that they missed a subsequent MC bleed after the vaccine. Formally, this does not provide enough evidence to quantify if the vaccine was the reason for this missing bleed. A review of 1273 MC's saw several reports of MC disruptions following the vaccine. However, there was no strong indication to advocate that the COVID-19 vaccine led to a change in the MC (Male, 2021). Overall, COVID-19 did influence athletes' training in both a positive and negative manner. Location and vaccine status may have impacted the MC; however, future research is required to gain a better understanding.

5.9 Limitations and future research

Due to the online nature of this study, determination of ovulation via urinary ovulation kits, BBT, and manual MC tracking were the three methods used to determine the MC phase. Thus, one limitation of this study was that hormonal verification via blood serum could not be conducted. Secondly, collecting training and race data from different GPS systems may have led to some inaccuracies in the data collected. The study was underpowered, and a larger cohort with an even discipline split is required to determine more significant values. In addition, it is recognised that this was a three-month study of daily data collection which may have led to reduced compliance over the data collection period. The reporting of MC related symptom was very subjective, and the severity of the symptoms could not be measured. There were some missing data for body mass due to athletes not having scales when travelling or lack of compliance to daily readings over the three months. Furthermore, it is recognised that the body mass measurements will not be as accurate. Future practitioners should consider this when creating methodologies with elite athletes that may travel for competition, and equipment such as scales, may not always be available.

One of the key findings which confirmed previous research was the rise in body temperature during the LP and discussed throughout as its sole effect on several other factors such as HR, sleep, RPE, arousal and alertness. Although previous research has observed mixed findings, research in lab-based environments is required to determine the optimal body temperature for performance and how this can be influenced in temperate, hot, and humid environments. Power is another important determinant in cycling performance, specifically when determining power to weight ratio with body mass. However, this data was removed as only a few athletes could provide accurate power values. Further research is required to determine if body mass changes across the MC have meaningful effects on power to weight ratios and consequently, performance in cyclists. Finally, in 2020 BASES released an expert statement providing guidelines to measure the MC over three months (Elliott-Sale et al., 2020). However, the findings from this study observed that there was no change across the three cycles, and a snapshot of one regular MC could have provided a similar picture. However, this cannot be applied to all populations, and more studies are required to understand if tracking the MC for three months is an accurate representation in different cohorts.

5.10 Conclusion

This study has allowed for a better understanding of how the MC influences the demands of mountain biking, road and cyclocross at a well-trained and elite level. There is a clear consensus that BBT rises in the LP. However, different phases of the MC did not influence body mass, training load, HR, RPE, sleep, arousal, and alertness. Additionally, presenting realistic training volumes and loads for female well-trained and elite mountain bike, road and cyclocross athlete's allowed for a better understanding of perceived sleep measures in a well-trained and elite cycling cohort.

Further lab-based studies are required to recognise the optimal exercising body temperature for performance and if this differs between the phases of the MC.

The study was underpowered, and thus a larger cohort is required to determine if the aforementioned findings could be significant. Furthermore, changes in the MC were reported during the COVID-19 pandemic. Athletes' training and race schedules were positively and negatively affected during this time. In conclusion, this study observed that the MC did not influence training schedules in well-trained and elite mountain bike, road and cyclocross athletes as a cohort. Nevertheless, individual responses were present, and it is recommended that coaches and athletes monitor their MC across their training

Chapter 6: References

6.0 References

Abdollahpor, A., Khosravi, N., & Zahra, N. R. (2013). Effects of the menstrual cycle phase on the blood lactate responses and exercise performance in active women. *European Journal of Experimental Biology*, *3*(3), 206-210. Retrieved from www.pelagiaresearchlibrary.com

Ahrend, M. D., Schneeweiss, P., Martus, P., Niess, A. M., & Krauss, I. (2018). Predictive ability of a comprehensive incremental test in mountain bike marathon. BMJ Open Sport & Exercise Medicine, 4(1), e000293. http://dx.doi.org/10.1136/bmjsem-2017-000293

Arent, S.M., & Landers, D.M. (2003) Arousal, Anxiety, and Performance: A Reexamination of the Inverted-U Hypothesis, *Research Quarterly for Exercise and Sport*, 74(4), 436-444, 10.1080/02701367.2003.10609113

Armour, M., Parry, K. A., Steel, K., & Smith, C. A. (2020). Australian female athlete perceptions of the challenges associated with training and competing when menstrual symptoms are present. *International Journal of Sports Science & Coaching*, *15*(3), 316-323. https://doi.org/10.1177/1747954120916073.

Azari, H., Nasiri, S., & Eghbali, E. (2019). Is there a difference toward strength, muscular endurance, anaerobic power and hormonal changes between the three phase of the menstrual cycle of active girls? *Apunts. Medicina de l'Esport*, 54(202), 65-72. https://doi.org/10.1016/j.apunts.2018.11.001

Baker, F. C., & Driver, H. S. (2004). Self-reported sleep across the menstrual cycle in young, healthy women. *Journal of psychosomatic research*, *56*(2), 239-243. https://doi.org/10.1016/S0022-3999(03)00067-9

Baker, F. C., & Driver, H. S. (2007). Circadian rhythms, sleep, and the menstrual cycle. *Sleep medicine*, *8*(6), 613-622. https://doi.org/10.1016/j.sleep.2006.09.011

Baker, F. C., Siboza, F., & Fuller, A. (2020). Temperature regulation in women: Effects of the menstrual cycle. *Temperature*, *7*(3), 226-262. https://doi.org/10.1080/23328940.2020.1735927

Bambaeichi, E., Reilly, T., Cable, N. T., & Giacomoni, M. (2004). The isolated and combined effects of menstrual cycle phase and time-of-day on muscle strength of eumenorrheic females. *Chronobiology International*, *21*(4-5), 645-660. https://doi.org/10.1081/CBI-120039206.

Banister E.W. (1991) Modelling athletic performance. In: MacDougall JD, Wenger HA, Green HJ (eds) *Physiological testing of the high-performance athlete*. Human Kinetics, Campaign, 403–425

Barron, M. L., & Fehring, R. J. (2005). Basal body temperature assessment: is it useful to couples seeking pregnancy? *MCN: The American Journal of Maternal/Child Nursing*, *30*(5), 290-296. Retrieved from: https://epublications.marquette.edu/cgi/viewcontent.cgi?article=1005&context=nursing_fac

Barreto, G., de Oliveira, L. F., Saito, T., Klosterhoff, R., Perim, P., Dolan, E., ... & Saunders, B. (2021). Reduced Endurance Capacity and Suboptimal Energy Availability in Top-Level Female Cyclists. *International Journal of Sports Physiology and Performance*, *16*(8), 1194-1203. https://doi.org/10.1123/ijspp.2020-0513

Barrett, B., Brown, R., Mundt, M., Safdar, N., Dye, L., Maberry, R., & Alt, J. (2005). The Wisconsin upper respiratory symptom survey is responsive, reliable, and valid. *Journal of clinical epidemiology*, *58*(6), 609-617. https://doi.org/10.1016/j.jclinepi.2004.11.019

Becker, J., & Moroder, P. (2017). Extreme mountain biking injuries. In *Extreme sports medicine* (pp. 139-150). Springer, Cham. https://doi.org/10.1007/978-3-319-28265-7_12

Blagrove, R. C., Bruinvels, G., & Pedlar, C. R. (2020). Variations in strength-related measures during the menstrual cycle in eumenorrheic women: A systematic review and meta-analysis. *Journal of Science and Medicine in Sport*, *23*(12), 1220-1227. https://doi.org/10.1016/j.jsams.2020.04.022

Borg, G. A. V. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise, 14*(5), 377–381. https://doi.org/10.1249/00005768-198205000-00012

Bossi, A. H., Lima, P., Lima, J. P. D., & Hopker, J. (2017). Laboratory predictors of uphill cycling performance in trained cyclists. *Journal of sports sciences*, *35*(14), 1364-1371. https://doi.org/10.1080/02640414.2016.1182199

Bowes, A., Lomax, L., & Piasecki, J. (2020). The impact of the COVID-19 lockdown on elite sportswomen. *Managing sport and leisure*, 1-17. https://doi.org/10.1080/23750472.2020.1825988

Bruinvels, G., Burden, R. J., McGregor, A. J., Ackerman, K. E., Dooley, M., Richards, T., & Pedlar, C. (2017). Sport, exercise and the menstrual cycle: where is the research?. British Journal of Sports Medicine, 51(6), 487-488. http://dx.doi.org/10.1136/bjsports-2016-096279

Bruinvels, G., Goldsmith, E., Blagrove, R., Simpkin, A., Lewis, N., Morton, K., ... Pedlar, C. (2021a). Prevalence and frequency of menstrual cycle symptoms are associated with availability to train and compete: a study of 6812 exercising women recruited using the Strava exercise app. *British Journal of Sports Medicine*, 55(8), 438-443. http://dx.doi.org/10.1136/bjsports-2020-102792.

Bruinvels, G., Lewis, N. A., Blagrove, R. C., Scott, D., Simpson, R. J., Baggish, A. L., ... Pedlar, C. R. (2021b). COVID-19–Considerations for the Female Athlete. *Frontiers in Sports and Active Living*, *3*, 22. https://doi.org/10.3389/fspor.2021.606799

Bull, J. R., Rowland, S. P., Scherwitzl, E. B., Scherwitzl, R., Danielsson, K. G., & Harper, J. (2019). Real-world menstrual cycle characteristics of more than 600,000 menstrual cycles. *NPJ digital medicine*, *2*(1), 1-8. https://doi.org/10.1038/s41746-019-0152-7

Burden, R., Shill, A., & Bishop, N. (2021). Elite female athlete research: stop searching for the 'magic P'. *Experimental Physiology*, 106(10), 2029-1030. https://doi.org/10.1113/EP089884

Burrows, M., Bird, S. R., & Bishop, N. (2002). The menstrual cycle and its effect on the immune status of female endurance runners. *Journal of sports sciences*, *20*(4), 339-344. https://doi.org/10.1080/026404102753576116

Campbell, S. E., Angus, D. J., & Febbraio, M. A. (2001). Glucose kinetics and exercise performance during phases of the menstrual cycle: effect of glucose ingestion. American Journal of Physiology-Endocrinology And Metabolism, 281(4), https://doi.org/10.1152/ajpendo.2001.281.4.E817

Carmichael, R.D., Heikkinen, D.J., Mullin, E.M., McCall, N.R., (2017). Physiological response to cyclocross racing. *Sport Exerc Med Open Journal*, 3(2): 74- 80. 10.17140/SEMOJ-3-152

Carmichael, M. A., Thomson, R. L., Moran, L. J., & Wycherley, T. P. (2021a). The Impact of Menstrual Cycle Phase on Athletes' Performance: A Narrative Review. *International journal of environmental research and public health*, *18*(4), 1667. https://doi.org/10.3390/ijerph18041667

Carmichael, M. A., Thomson, R. L., Moran, L. J., Dunstan, J. R., Nelson, M. J., Mathai, M. L., & Wycherley, T. P. (2021b). A Pilot Study on the Impact of Menstrual Cycle Phase on Elite Australian Football Athletes. *International Journal of Environmental Research and Public Health*, *18*(18), 9591. https://doi.org/10.3390/ijerph18189591

Carskadon, M. A., & Dement, W. C. (2005). Normal human sleep: an overview. *Principles and practice of sleep medicine*, *4*, 13-23. 10.1016/B0-72-160797-7/50009-4

Casazza, G. A., Suh, S. H., Miller, B. F., Navazio, F. M., & Brooks, G. A. (2002). Effects of oral contraceptives on peak exercise capacity. *Journal of Applied Physiology*, *93*(5), 1698-1702. https://doi.org/10.1152/japplphysiol.00622.2002

Casazza, G. A., Jacobs, K. A., Suh, S. H., Miller, B. F., Horning, M. A., & Brooks, G. A. (2004). Menstrual cycle phase and oral contraceptive effects on triglyceride mobilization during exercise. Journal of Applied Physiology, 97(1), 302-309. https://doi.org/10.1152/japplphysiol.00050.2004

Castanier, C., Bougault, V., Teulier, C., Jaffré, C., Schiano-Lomoriello, S., Vibarel-Rebot, N., ... & Collomp, K. (2021). The specificities of elite female athletes: A multidisciplinary approach. *Life*, *11*(7), 622. https://doi.org/10.3390/life11070622

Charkoudian, N., & Stachenfeld, N. (2016). Sex hormone effects on autonomic mechanisms of thermoregulation in humans. *Autonomic Neuroscience*, *196*, 75-80. https://doi.org/10.1016/j.autneu.2015.11.004

Chatterton, R. T., Mateo, E. T., Hou, N., Rademaker, A. W., Acharya, S., Jordan, V. C., & Morrow, M. (2005). Characteristics of salivary profiles of oestradiol and progesterone in premenopausal women. *Journal of Endocrinology*, *186*(1), 77-84. https://doi.org/10.1677/joe.1.06025

Chidley, J. B., MacGregor, A. L., Martin, C., Arthur, C. A., & Macdonald, J. H. (2015). Characteristics explaining performance in downhill mountain biking. *International journal of sports physiology and performance*, *10*(2), 183-190. 10.1123/ijspp.2014-0135

Cohen, S., Kamarck, T., & Mermelstein, R. (1994). Perceived stress scale. *Measuring stress: A guide for health and social scientists*, *10*(2), 1-2.

Copenhaver, E. A., & Diamond, A. B. (2017). The value of sleep on athletic performance, injury, and recovery in the young athlete. *Pediatric annals*, *46*(3), e106-e111. 10.3928/19382359-20170221-01

Cristina-Souza, G., Santos-Mariano, A. C., Souza-Rodrigues, C. C., Osiecki, R., Silva, S. F., Lima-Silva, A. E., & De Oliveira, F. R. (2019). Menstrual cycle alters training strain, monotony, and technical training length in young. *Journal of Sports Sciences*, *37*(16), 1824-1830. https://doi.org/10.1080/02640414.2019.1597826

Dasa, M. S., Kristoffersen, M., Ersvær, E., Bovim, L. P., Bjørkhaug, L., Moe-Nilssen, R., ... Haukenes, I. (2021). The Female Menstrual Cycles Effect on Strength and Power Parameters in High-Level Female Team Athletes. *Frontiers in Physiology*, *12*, 164. https://doi.org/10.3389/fphys.2021.600668

De Souza, M. J. (2003). Menstrual disturbances in athletes: a focus on luteal phase defects. *Medicine & Science in Sports & Exercise*, *35*(9), 1553–1563. https://doi.org/10.1249/01.MSS.0000084530.31478.DF

Dean, T. M., Perreault, L., Mazzeo, R. S., & Horton, T. J. (2003). No effect of menstrual cycle phase on lactate threshold. *Journal of Applied Physiology*, *95*(6), 2537-2543. https://doi.org/10.1152/japplphysiol.00672.2003

Decroix, L., De Pauw, K., Foster, C., & Meeusen, R. (2016). Guidelines to classify female subject groups in sport-science research. *International Journal of Sports Physiology and Performance*, 11(2), 204–213. https://doi.org/10.1123/ijspp.2015-0153

Desbrow, B., Burd, N. A., Tarnopolsky, M., Moore, D. R., & Elliott-Sale, K. J. (2019). Nutrition for special populations: Young, female, and masters athletes. *International journal of sport nutrition and exercise metabolism*, *29*(2), 220-227. https://doi.org/10.1123/ijsnem.2018-0269

Draper, C. F., Duisters, K., Weger, B., Chakrabarti, A., Harms, A. C., Brennan, L., ... & Van Der Greef, J. (2018). Menstrual cycle rhythmicity: metabolic patterns in healthy women. *Scientific reports*, *8*(1), 1-15. https://doi.org/10.1038/s41598-018-32647-0

Driver, H. S., Dijk, D. J., Werth, E., Biedermann, K., & Borbely, A. A. (1996). Sleep and the sleep electroencephalogram across the menstrual cycle in young healthy women. *The Journal of Clinical Endocrinology & Metabolism*, *81*(2), 728-735. 10.1210/jcem.81.2.8636295

Drust, B., Waterhouse, J., Atkinson, G., Edwards, B., & Reilly, T. (2005). Circadian rhythms in sports performance—an update. *Chronobiology International*, *22*(1), 21-44. https://doi.org/10.1081/CBI-200041039

Elliott-Sale, K. J., McNulty, K. L., Ansdell, P., Goodall, S., Hicks, K. M., Thomas, K., ... & Dolan, E. (2020). The effects of oral contraceptives on exercise performance in women: a systematic review and meta-analysis. *Sports medicine*, 1-28. https://doi.org/10.1007/s40279-020-01317-5

Elliott-Sale, K., Ross, E., Burden, R., & Hicks, K. (2020). The BASES expert statement on conducting and implementing female athlete-based research. *The Sport and Exercise Scientist*, (65), 6-7. ISSN 1754-3444

Emmonds, S., Heyward, O. & Jones, B. The Challenge of Applying and Undertaking Research in Female Sport. *Sports Med - Open* **5,** 51 (2019). https://doi.org/10.1186/s40798-019-0224-x

Ergin, E., & Kartal, A. (2020). Menstrual Cycle and Sporting Performance Perceptions of Elite Volleyball Players. *International Journal of Applied Exercise Physiology*, *9*(10), 57-64. 10.26655/IJAEP.2020.10.1

Findlay, R. J., Macrae, E. H., Whyte, I. Y., Easton, C., & Forrest, L. J. (2020). How the menstrual cycle and menstruation affect sporting performance: experiences and perceptions of elite female rugby players. *British journal of sports medicine*, *54*(18), 1108-1113. http://dx.doi.org/10.1136/bjsports-2019-101486

Forsyth, J., & Roberts, C. M. (Eds.). (2018). *The exercising female: science and its application*. Routledge.

Frankovich, R. J., & Lebrun, C. M. (2000). Menstrual cycle, contraception, and performance. *Clinics in sports medicine*, *19*(2), 251-271. https://doi.org/10.1016/S0278-5919(05)70202-7

Freemas, J. A., Baranauskas, M. N., Constantini, K., Constantini, N., Greenshields, J. T., Mickleborough, T. D., Schlader, Z. J. (2020). Exercise Performance Is Impaired during the Mid-Luteal Phase of the Menstrual Cycle. *Medicine and Science in Sports and Exercise*. 53(2), 442-452. https://doi.org/10.1249/MSS.0000000000002464

Gandara, & Leresche, I. (2007). Patterns of salivary estradiol and progesterone across the menstrual cycle. *Annals of the new york academy of sciences.*, *1098*(1), 446–450. Https://doi.org/10.1196/annals.1384.022

Garcia, A. M. C., Lacerda, M. G., Fonseca, I. A. T., Reis, F. M., Rodrigues, L. O. C., & Silami-Garcia, E. (2006). Luteal phase of the menstrual cycle increases sweating rate during exercise. *Brazilian Journal of Medical and Biological Research*, *39*(9), 1255-1261. https://doi.org/10.1590/S0100-879X2006005000007

García-Pinillos, F., Bujalance-Moreno, P., Lago-Fuentes, C., Ruiz-Alias, S. A., Domínguez-Azpíroz, I., Mecías-Calvo, M., & Ramirez-Campillo, R. (2021). Effects of the Menstrual Cycle on Jumping, Sprinting and Force-Velocity Profiling in Resistance-Trained Women: A Preliminary Study. *International Journal of Environmental Research and Public Health*, *18*(9), 4830. https://doi.org/10.3390/ijerph18094830

Gleeson, M., & Pyne, D. B. (2016). Respiratory inflammation and infections in high-performance athletes. *Immunology and cell biology*, *94*(2), 124-131. doi: https://doi.org/10.1038/icb.2015.100

Grant, L. K., Gooley, J. J., St Hilaire, M. A., Rajaratnam, S. M., Brainard, G. C., Czeisler, C. A., ... & Rahman, S. A. (2020). Menstrual phase-dependent differences in neurobehavioral performance: the role of temperature and the progesterone/estradiol ratio. *Sleep*, *43*(2), zsz227. https://doi.org/10.1093/sleep/zsz227

Gregory, J., Johns, D. P., & Walls, J. T. (2007). Relative vs. absolute physiological measures as predictors of mountain bike cross-country race performance. The Journal of Strength & Conditioning Research, 21(1), 17-22.

Haakonssen, E. C., Barras, M., Burke, L. M., Jenkins, D. G., & Martin, D. T. (2016). Body composition of female road and track endurance cyclists: Normative values and typical changes. *European journal of sport science*, *16*(6), 645-653. https://doi.org/10.1080/17461391.2015.1084538

Hackney, A. C. (1999). Influence of oestrogen on muscle glycogen utilization during exercise. *Acta physiologica scandinavica*, *167*(3), 273. https://doi-org.napier.idm.oclc.org/10.1046/j.1365-201x.1999.00605.x

Hackney, A. C., Koltun, K. J., & Williett, H. N. (2022). Menstrual cycle hormonal changes: estradiol-β-17 and progesterone interactions on exercise fat oxidation. *Endocrine*, 1-3. https://doi.org/10.1007/s12020-022-02998-w

Halson, S. L. (2014). Sleep in elite athletes and nutritional interventions to enhance sleep. *Sports Medicine*, *44*(1), 13-23. https://doi.org/10.1007/s40279-014-0147-0

Händel, P., & Wahlström, J. (2019). Digital contraceptives based on basal body temperature measurements. *Biomedical Signal Processing and Control*, 52, 141-151. https://doi.org/10.1016/j.bspc.2019.04.019

Harlow, S. D., & Matanoski, G. M. (1991). The association between weight, physical activity, and stress and variation in the length of the menstrual cycle. American journal of epidemiology, 133(1), 38-49. https://doi.org/10.1093/oxfordjournals.aje.a115800

Harrison, G. E., Vickers, E., Fletcher, D., & Taylor, G. (2020). Elite female soccer players' dual career plans and the demands they encounter. *Journal of Applied Sport Psychology*, 1-22. https://doi.org/10.1080/10413200.2020.1716871

Hashimoto, H., Ishijima, T., Hayashida, H., Suzuki, K., & Higuchi, M. (2014). Menstrual cycle phase and carbohydrate ingestion alter immune response following endurance exercise and high intensity time trial performance test under hot conditions. *Journal of the International Society of Sports Nutrition*, *11*(1), 1-11. https://doi.org/10.1186/1550-2783-11-39

Hays, A., Devys, S., Bertin, D., Marquet, L. A., & Brisswalter, J. (2018). Understanding the physiological requirements of the mountain bike cross-country Olympic race format. *Frontiers in Physiology*, 1062. https://doi.org/10.3389/fphys.2018.01062

He, C. S., Bishop, N., Handzlik, M. K., Muhamad, A. S., & Gleeson, M. (2014). Sex differences in upper respiratory symptoms prevalence and oral-respiratory mucosal immunity in endurance athletes. *Exercise Immunology Review*, 20, 8-22. Retrieved from: https://pubmed.ncbi.nlm.nih.gov/24974718/

Heathcote, S. L., Hassmén, P., Zhou, S., & Stevens, C. J. (2018). Passive heating: reviewing practical heat acclimation strategies for endurance athletes. *Frontiers in Physiology*, 9, 1851. https://doi.org/10.3389/fphys.2018.01851

Hirshkowitz, M., Whiton, K., Albert, S. M., Alessi, C., Bruni, O., DonCarlos, L., ... & Hillard, P. J. A. (2015). National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep health*, *1*(1), 40-43. https://doi.org/10.1016/j.sleh.2014.12.010

Hoddes, E., et al. "Quantification of sleepiness: a new approach." Psychophysiology 10.4 (1973): 431-436. https://doi.org/10.1111/j.1469-8986.1973.tb00801.x

Horne, J. A., & Östberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International journal of chronobiology*.

Hurst, H. T., & Atkins, S. (2006). Power output of field-based downhill mountain biking. *Journal of Sports Sciences*, *24*(10), 1047-1053. https://doi.org/10.1080/02640410500431997

Hurst, H. T., Swarén, M., Hébert-Losier, K., Ericsson, F., Sinclair, J. K., Atkins, S., & Holmberg, H. C. (2012). Influence of course type on upper body muscle activity in elite cross-country and downhill mountain bikers during off road downhill cycling. *Journal of Science and Cycling (JSC)*, *1*(2), 2-9. Retrieved from: http://clok.uclan.ac.uk/7482/

Impellizzeri, F. M., & Marcora, S. M. (2007). The physiology of mountain biking. Sports medicine, 37(1), 59-71. https://doi.org/10.2165/00007256-200737010-00005

Impellizzeri, F. M., Ebert, T., Sassi, A., Menaspa, P., Rampinini, E., & Martin, D. T. (2008). Level ground and uphill cycling ability in elite female mountain bikers and road cyclists. *European journal of applied physiology*, *102*(3), 335-341. https://doi.org/10.1007/s00421-007-0590-9

Janse de Jonge, X. A. (2003). Effects of the menstrual cycle on exercise performance. *Sports medicine*, *33*(11), 833-851. https://doi.org/10.2165/00007256-200333110-00004

Janse de Jonge, X.A., Thompson, M.W., Chuter, V.H., Silk, L.N., & Thom, J.M. (2012). Exercise performance over the menstrual cycle in temperate and hot, humid conditions. *Medicine and Science in Sports and Exercise,* 44(11). 2190-2198. 10.1249/mss.0b013e3182656f13.

Janse de Jonge, X.A., Thompson, B., & Han, A. (2019). Methodological Recommendations for Menstrual Cycle Research in Sports and Exercise. *Medicine and science in sports and exercise*, *51*(12), 2610-2617. 10.1249/mss.0000000000002073

Julian, R., Hecksteden, A., Fullagar, H. H., & Meyer, T. (2017). The effects of menstrual cycle phase on physical performance in female soccer players. *PloS one*, *12*(3), e0173951. https://doi.org/10.1371/journal.pone.0173951

Kirkwood, L. A., Taylor, M. D., Ingram, L. A., Malone, E., & Florida-James, G. D. (2019). Elite mountain bike enduro competition: a study of rider hand-arm vibration exposure. *Journal of Science and Cycling*, *8*(1), 18-25. 10.28985/171231.jsc.09

Kirkwood, L. A., Taylor, M. D., Ingram, L. A., Malone, E., & Florida-James, G. D. (2019). Elite mountain bike enduro competition: a study of rider hand-arm vibration exposure. *Journal of Science and Cycling*, *8*(1), 18-25. 10.28985/171231.jsc.09

Kirkwood, L. A. (2019). Performance in enduro mountain biking: the influence of training status, recovery, and vibration (Doctoral dissertation, Edinburgh Napier University).

Kirkwood, L. A., Taylor, M. D., Ingram, L. A., Malone, E., & Florida-James, G. D. (2019). Elite mountain bike enduro competition: a study of rider hand-arm vibration exposure. *Journal of Science and Cycling*, *8*(1), 18-25. https://doi.org/10.28985/1906.jsc.04

Kishali, N. F., Imamoglu, O., Katkat, D., Atan, T., & Akyol, P. (2006). Effects of menstrual cycle on sports performance. *International Journal of Neuroscience*, *116*(12),1549-1563. https://doi.org/10.1080/00207450600675217

Koikawa, N., Shimada, S., Suda, S., Murata, A., & Kasai, T. (2016). Sex differences in subjective sleep quality, sleepiness, and health-related quality of life among collegiate soccer players. *Sleep and Biological Rhythms*, *14*(4), 377-386. https://doi.org/10.1007/s41105-016-0068-4

Koikawa, N., Takami, Y., Kawasaki, Y., Kawana, F., Shiroshita, N., Ogasawara, E., & Kasai, T. (2020). Changes in the objective measures of sleep between the initial nights of menses and the nights during the midfollicular phase of the menstrual cycle in collegiate female athletes. *Journal of Clinical Sleep Medicine*, *16*(10), 1745-1751. 10.5664/jcsm.8692

Kose, B. (2018). Analysis of the Effect of Menstrual Cycle Phases on Aerobic-Anaerobic Capacity and Muscle Strength. *Journal of Education and Training Studies*, 6(8), 23-28. 10.11114/jets.v6i8.3207

Lamberts, & Davidowitz, K. J. (2014). Allometric Scaling and Predicting Cycling Performance in (Well-) Trained Female Cyclists. *International Journal of Sports Medicine*, *35*(3), 217–222. https://doi.org/10.1055/s-0033-1349139

Lamberts, R. P. (2014). Predicting cycling performance in trained to elite male and female cyclists. International Journal of Sports Physiology and Performance, 9(4), 610-614. https://doi.org/10.1123/ijspp.2013-0040a

Lastella, M., Roach, G. D., Halson, S. L., & Sargent, C. (2016). The chronotype of elite athletes. *Journal of human kinetics*, *54*(1), 219-225. 10.1515/hukin-2016-0049

Lastella, M., Miller, D. J., Quilelli, M., Roberts, S., Aisbett, B., & Condo, D. (2021). The impact of chronotype on the sleep and training responses of elite female Australian footballers. *Clocks & Sleep*, *3*(4), 528-535. https://doi.org/10.3390/clockssleep3040037

Lee, H., Martin, D. T., Anson, J. M., Grundy, D., & Hahn, A. G. (2002). Physiological characteristics of successful mountain bikers and professional road cyclists. Journal of Sports Sciences, 20(12), 1001-1008. https://doi.org/10.1080/026404102321011760

Leeder, J., Glaister, M., Pizzoferro, K., Dawson, J., & Pedlar, C. (2012) Sleep duration and quality in elite athletes measured using wristwatch actigraphy, J*ournal of Sports Sciences*, 30:6, 541-545. 10.1080/02640414.2012.660188

Logue, D., Madigan, S. M., Delahunt, E., Heinen, M., Mc Donnell, S. J., & Corish, C. A. (2018). Low energy availability in athletes: a review of prevalence, dietary patterns, physiological health, and sports performance. *Sports Medicine*, *48*(1), 73-96. https://doi.org/10.1007/s40279-017-0790-3

Logue, D. M., Madigan, S. M., Melin, A., Delahunt, E., Heinen, M., Donnell, S. J. M., & Corish, C. A. (2020). Low energy availability in athletes 2020: an updated narrative review of prevalence, risk, within-day energy balance, knowledge, and impact on sports performance. *Nutrients*, *12*(3), 835. 10.3390/nu12030835

Ludyga, S., Gronwald, T., & Hottenrott, K. (2016). The athlete's brain: cross-sectional evidence for neural efficiency during cycling exercise. Neural Plasticity, 2016. https://doi.org/10.1155/2016/4583674

Maciejczyk, M., Wiecek, M., Szymura, J., Szygula, Z., & Brown, L. E. (2015). Influence of increased body mass and body composition on cycling anaerobic power. *The Journal of Strength & Conditioning Research*, *29*(1), 58-65. 10.1519/JSC.0000000000000727

Male, V. (2021). Menstrual changes after covid-19 vaccination. *BMJ*, *374*. https://doi.org/10.1136/bmj.n2211

Malm, C. (2006). Susceptibility to infections in elite athletes: the S-curve. Scandinavian journal of medicine & science in sports, 16(1), 4-6. https://doi.org/10.1111/j.1600-0838.2005.00499.x

Maughan, R., & Shirreffs, S. (2004). Exercise in the heat: challenges and opportunities. Journal of Sports Sciences, 22(10), 917-927. doi: https://doi.org/10.1080/02640410400005909

Marsh, S. A., & Jenkins, D. G. (2002). Physiological responses to the menstrual cycle. *Sports Medicine*, *32*(10), 601-614. https://doi.org/10.2165/00007256-200232100-00001

Martin, D. T., McLean, B., Trewin, C., Lee, H., Victor, J., & Hahn, A. G. (2001). Physiological characteristics of nationally competitive female road cyclists and demands of competition. *Sports Medicine*, *31*(7), 469-477. https://doi.org/10.2165/00007256-200131070-00002

McNamara, D. A., Harris, D. R., and Minahan, A. C. (2020). *Menstrual Cycle Change During COVID-19. Sharing Some Early Results*. Available online at: https://blogs.bmj.com/bjsm/2020/11/20/menstrual-cycle-change-during-covid-19/

McNulty, K.L., Elliott-Sale, K.J., Dolan, E. *et al* (2020). The Effects of Menstrual Cycle Phase on Exercise Performance in Eumenorrheic Women: A Systematic Review and Meta-Analysis. *Sports Med,* 50, 1813–1827. https://doi.org/10.1007/s40279-020-01319-3

McGovern, P. G., Myers, E. R., Silva, S., Coutifaris, C., Carson, S. A., Legro, R. S., ... & NICHD National Cooperative Reproductive Medicine Network. (2004). Absence of secretory endometrium after false-positive home urine luteinizing hormone testing. *Fertility and sterility*, *82*(5), 1273-1277. https://doi.org/10.1016/j.fertnstert.2004.03.070

Mehrsafar, A. H., Rosa, M. A. S., Zadeh, A. M., & Gazerani, P. (2020). A feasibility study of application and potential effects of a single session transcranial direct current stimulation (tDCS) on competitive anxiety, mood state, salivary levels of cortisol and alpha amylase in elite athletes under a real-world competition. Physiology & Behavior, 227, 113173. https://doi.org/10.1016/j.physbeh.2020.113173

Melin, A. (2014). The LEAF questionnaire: a screening tool for the identification of female athletes at risk for the female athlete triad. *British Journal of Sports Medicine.*, *48*(7), 540–545. https://doi.org/10.1136/bjsports-2013-093240

Middleton, L. E., & Wenger, H. A. (2006). Effects of menstrual phase on performance and recovery in intense intermittent activity. *European Journal of Applied Physiology*, *96*(1), 53-58. https://doi.org/10.1007/s00421-005-0073-9

Mihm, M., S. Gangooly, and S. Muttukrishna. "The normal menstrual cycle in women." Animal reproduction science 124.3-4 (2011): 229-236.https://doi.org/10.1016/j.anireprosci.2010.08.030

Montgomery, M. M., & Shultz, S. J. (2010). Isometric knee-extension and knee-flexion torque production during early follicular and postovulatory phases in recreationally active women. *Journal of athletic training*, *45*(6), 586-593. https://doi.org/10.4085/1062-6050-45.6.586

Mujika, I., & Padilla, S. (2001). Physiological and performance characteristics of male professional road cyclists. *Sports medicine*, *31*(7), 479-487. https://doi.org/10.2165/00007256-200131070-00003

Mujika, I., & Taipale, R. S. (2019). Sport science on women, women in sport science. *International Journal of Sports Physiology and Performance*, *14*(8), 1013-1014. https://doi.org/10.1123/ijspp.2019-0514

Myllyaho, M. M., Ihalainen, J. K., Hackney, A. C., Valtonen, M., Nummela, A., Vaara, E., ... & Taipale, R. S. (2021). Hormonal contraceptive use does not affect strength, endurance, or body composition adaptations to combined strength and endurance training in women. *The Journal of Strength & Conditioning Research*, *35*(2), 449-457. 10.1519/JSC.0000000000002713

Nedelec, M., Aloulou, A., Duforez, F., Meyer, T., & Dupont, G. (2018). The variability of sleep among elite athletes. Sports medicine-open, 4(1), 1-13. https://doi.org/10.1186/s40798-018-0151-2

Novak, A. R., Bennett, K. J., Fransen, J., & Dascombe, B. J. (2018). A multidimensional approach to performance prediction in Olympic distance cross-country mountain bikers. Journal of sports sciences, 36(1), 71-78. https://doi.org/10.1080/02640414.2017.1280611

Oosthuyse, T., Bosch, A. N., & Jackson, S. (2005). Cycling time trial performance during different phases of the menstrual cycle. *European Journal of Applied Physiology*, *94*(3), 268-276. https://doi.org/10.1007/s00421-005-1324-5

Oosthuyse, T., & Bosch, A. N. (2010). The effect of the menstrual cycle on exercise metabolism. *Sports medicine*, *40*(3), 207-227. https://doi.org/10.2165/11317090-000000000-00000

Oosthuyse, T., & Bosch, A. N. (2012). Oestrogen's regulation of fat metabolism during exercise and gender specific effects. Current opinion in pharmacology, 12(3), 363-371. https://doi.org/10.1016/j.coph.2012.02.008

Otter, R. T., Brink, M. S., van der Does, H. T., & Lemmink, K. A. (2016). Monitoring perceived stress and recovery in relation to cycling performance in female athletes. *International journal of sports medicine*, *37*(01), 12-18.10.1055/s-0035-1555779

Pallavi, L. C., Souza, U. J. D., & Shivaprakash, G. (2017). Assessment of musculoskeletal strength and levels of fatigue during different phases of menstrual cycle in young adults. *Journal of Clinical and Diagnostic Research: JCDR*, *11*(2), CC11. 10.7860/JCDR/2017/24316.9408

Patel, A. K., Reddy, V., & Araujo, J. F. (2020). Physiology, sleep stages. *StatPearls [Internet]*. Retrieved from: https://www.ncbi.nlm.nih.gov/books/NBK526132/

Phillips, K. E., & Hopkins, W. G. (2020). Determinants of cycling performance: a review of the dimensions and features regulating performance in elite cycling competitions. *Sports medicine-open*, *6*(1), 1-18. https://doi.org/10.1186/s40798-020-00252-z

Pitchers, G., & Elliot-Sale, K. (2019). Considerations for coaches training female athletes. *Prof Strength Cond*, *55*, 19-30.

Pivarnik, J. M., Marichal, C. J., Spillman, H. T., & Morrow, J. R. (1992). Menstrual cycle phase affects temperature regulation during endurance exercise. *Medicine and Science in Sports and Exercise*, *22*(2), S119–. https://doi.org/10.1249/00005768-199004000-00708

Pomportes, L., Brisswalter, J., & Davranche, K. (2021). Carbohydrate-electrolyte ingestion enhances cognitive performance during a cross-country mountain biking race. https://doi.org/10.31234/osf.io/wvteb

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Rae, D. E., Stephenson, K. J., & Roden, L. C. (2015). Factors to consider when assessing diurnal variation in sports performance: the influence of chronotype and habitual training time-of-day. *European journal of applied physiology*, *115*(6), 1339-1349. https://doi.org/10.1007/s00421-015-3109-9

Rael, B., Alfaro-Magallanes, V. M., Romero-Parra, N., Castro, E. A., Cupeiro, R., Janse de Jonge, X. A., ... & IronFEMME Study Group. (2021). Menstrual cycle phases influence on cardiorespiratory response to exercise in endurance-trained females. *International Journal of Environmental Research and Public Health*, *18*(3), 860. https://doi.org/10.3390/ijerph18030860

Redman, L. M., & Weatherby, R. P. (2004). Measuring performance during the menstrual cycle: a model using oral contraceptives. Medicine & science in sports & exercise, 36(1), 130-136. 10.1249/01.MSS.0000106181.52102.99

Romans, S. E., Kreindler, D., Einstein, G., Laredo, S., Petrovic, M. J., & Stanley, J. (2015). Sleep quality and the menstrual cycle. *Sleep medicine*, *16*(4), 489-495. 10.1016/j.sleep.2014.12.001

Romero-Moraleda, B., Del Coso, J., Gutiérrez-Hellín, J., Ruiz-Moreno, C., Grgic, J., & Lara, B. (2019). The influence of the menstrual cycle on muscle strength and power performance. *Journal of Human Kinetics*, *68*, 123. 10.2478/hukin-2019-0061

Roos, J., Johnson, S., Weddell, S., Godehardt, E., Schiffner, J., Freundl, G., & Gnoth, C. (2015). Monitoring the menstrual cycle: Comparison of urinary and serum reproductive hormones referenced to true ovulation. *The European Journal of Contraception & Reproductive Health Care*, *20*(6), 438-450. https://doi.org/10.3109/13625187.2015.1048331

RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA

Sargent, C., Lastella, M., Halson, S. L., & Roach, G. D. (2014). The impact of training schedules on the sleep and fatigue of elite athletes. *Chronobiology international*, *31*(10), 1160-1168. https://doi.org/10.3109/07420528.2014.957306

Sargent, C., Lastella, M., Halson, S. L., & Roach, G. D. (2021). How much sleep does an elite athlete need?. *International Journal of Sports Physiology and Performance*, *16*(12), 1746-1757. https://doi.org/10.1123/ijspp.2020-0896

Sarto, F., Impellizzeri, F. M., Spörri, J., Porcelli, S., Olmo, J., Requena, B., ... & Franchi, M. V. (2020). Impact of potential physiological changes due to COVID-19 home confinement on athlete health protection in elite sports: a call for awareness in sports programming. *Sports medicine*, *50*(8), 1417-1419. https://doi.org/10.1007/s40279-020-01297-6

Saunders, B., Barreto, G., de Oliveira, L. F., Saito, T., Klosterhoff, R., Perim, P. H. L., ... & Lima, F. (2019). A year in the life of a Brazilian professional female road cycling team–Part I: Performance measures. *Journal of Science and Cycling*, *8*(2), 45-47. Retrieved from: https://www.jsc-journal.com/index.php/JSC/article/view/488

Saunders, D., Abt, G., Hesselink, M. K., Myers, T., & Akubat, I. (2017). Methods of monitoring training load and their relationships to changes in fitness and performance in competitive road cyclists. *International journal of sports physiology and performance*, *12*(5), 668-675. https://doi.org/10.1123/ijspp.2016-0454

Schaumberg, M. A., Jenkins, D. G., de Jonge, X. A. J., Emmerton, L. M., & Skinner, T. L. (2017). Three-step method for menstrual and oral contraceptive cycle verification. Journal of Science and Medicine in Sport, 20(11), 965-969. https://doi.org/10.1016/j.jsams.2016.08.013

Shechter, A., Varin, F., & Boivin, D. B. (2010). Circadian variation of sleep during the follicular and luteal phases of the menstrual cycle. *Sleep*, *33*(5), 647-656. https://doi.org/10.1093/sleep/33.5.647

Shibata, S., & Tahara, Y. (2014). Circadian rhythm and exercise. *The Journal of Physical Fitness and Sports Medicine*, *3*(1), 65-72. 10.7600/jpfsm.3.65

Simpson, N. S., Gibbs, E. L., & Matheson, G. O. (2017). Optimizing sleep to maximize performance: implications and recommendations for elite athletes. *Scandinavian journal of medicine & science in sports*, *27*(3), 266-274. doi: https://doi.org/10.1111/sms.12703

Silva, A., Narciso, F. V., Rosa, J. P., Rodrigues, D. F., da Silva Cruz, A. Â., Tufik, S., ... & De Mello, M. T. (2019). Gender differences in sleep patterns and sleep complaints of elite athletes. *Sleep Science*, *12*(4), 242. 10.5935/1984-0063.20190084

Slade, P., Haywood, A., & King, H. (2009). A qualitative investigation of women's experiences of the self and others in relation to their menstrual cycle. *British journal of health psychology*, *14*(1), 127-141. https://doi.org/10.1348/135910708X304441

Smekal, G., Von Duvillard, S. P., Frigo, P., Tegelhofer, T., Pokan, R., Hofmann, P., ... & Bachl, N. (2007). Menstrual cycle: no effect on exercise cardiorespiratory variables or blood lactate concentration. *Medicine and science in sports and exercise*, *39*(7), 1098. 10.1249/mss.0b013e31805371e7

Solli, G. S., Sandbakk, S. B., Noordhof, D. A., Ihalainen, J. K., & Sandbakk, Ø. (2020). Changes in Self-Reported Physical Fitness, Performance, and Side Effects Across the Phases of the Menstrual Cycle Among Competitive Endurance

Athletes. *International Journal of Sports Physiology and Performance*, *15*(9), 1324-1333. https://doi.org/10.1123/ijspp.2019-0616

Somboonwong, J., Chutimakul, L., & Sanguanrungsirikul, S. (2015). Core temperature changes and sprint performance of elite female soccer players after a 15-minute warm-up in a hot-humid environment. *The Journal of Strength & Conditioning Research*, *29*(1), 262-269. 10.1519/01.JSC.0000491321.12969.1d

Spence, L., Brown, W. J., Pyne, D. B., Nissen, M. D., Sloots, T. P., McCormack, J. G., ... & Fricker, P. A. (2007). Incidence, etiology, and symptomatology of upper respiratory illness in elite athletes. *Medicine and science in sports and exercise*, *39*(4), 577. 10.1249/mss.0b013e31802e851a

Steward, K., & Raja, A. (2020). Physiology, Ovulation And Basal Body Temperature. *StatPearls [Internet]*. Retrieved from: https://www.ncbi.nlm.nih.gov/books/NBK546686/

Stone, T., Earley, R. L., Burnash, S. G., & Wingo, J. E. (2020). Menstrual cycle effects on cardiovascular drift and maximal oxygen uptake during exercise heat stress. *European Journal of Applied Physiology*, *121*(2), 561–572. https://doi.org/10.1007/s00421-020-04542-y

Su, H. W., Yi, Y. C., Wei, T. Y., Chang, T. C., & Cheng, C. M. (2017). Detection of ovulation, a review of currently available methods. *Bioengineering & translational medicine*, 2(3), 238-246. https://doi.org/10.1002/btm2.10058

Sunderland, C., & Nevill, M. (2003). Effect of the menstrual cycle on performance of intermittent, high-intensity shuttle running in a hot environment. European journal of applied physiology, 88(4), 345-352. https://doi.org/10.1007/s00421-002-0722-1

Szmuilowicz, E. D., Adler, G. K., Williams, J. S., Green, D. E., Yao, T. M., Hopkins, P. N., & Seely, E. W. (2006). Relationship between aldosterone and progesterone in the human menstrual cycle. *The Journal of Clinical Endocrinology & Metabolism*, *91*(10), 3981-3987. https://doi.org/10.1210/jc.2006-1154

The International Olympic Committee (IOC). (2021). Retrieved from: https://www.olympic.org/women-in-sport/background/statistics

Thun, E., Bjorvatn, B., Flo, E., Harris, A., & Pallesen, S. (2015). Sleep, Circadian Rhythms, and Athletic Performance. *Sleep medicine reviews*, 23, 1-9. https://doi.org/10.1016/j.smrv.2014.11.003

Tomazo-Ravnik, T., Jakopič, V. Changes in Total Body Water and Body Fat in Young Women in the Course of Menstrual Cycle (2006). *Intl Jnl Anthropology* 21, 55–60. https://doi.org/10.1007/s11599-006-9007-0

Toresdahl, B. G., & Asif, I. M. (2020). Coronavirus disease 2019 (COVID-19): considerations for the competitive athlete. *Sports health*, *12*(3), 221-224. https://doi.org/10.1177/1941738120918876

Tsampoukos, A., Peckham, E. A., James, R., & Nevill, M. E. (2010). Effect of menstrual cycle phase on sprinting performance. *European journal of applied physiology*, *109*(4), 659-667. https://doi.org/10.1007/s00421-010-1384-z

UCI. (2019). UCI cycling regulations: Part IV Mountain bike races. Union Cycliste Internationale. Retrieved from: https://www.uci.org/regulations/3MyLDDrwJCJJ0BGGOFzOat#part-iv-mountain-bike

UCI. (2022). A Deserved Place For Women's Cycling. Union Cycliste Internationale. Retrieved from: https://www.uci.org/women-cycling/4mLSVS9JjVsfxchbscypD1

Vaiksaar, S., Jürimäe, J., Mäestu, J., Purge, P., Kalytka, S., Shakhlina, L., & Jürimäe, T. (2011). No effect of menstrual cycle phase and oral contraceptive use on endurance performance in rowers. *The Journal of Strength & Conditioning Research*, *25*(6), 1571-1578. 10.1519/JSC.0b013e3181df7fd2

Van Erp, T., Sanders, D., & De Koning, J. J. (2019). Training characteristics of male and female professional road cyclists: a 4-year retrospective analysis. *International journal of sports physiology and performance*, *15*(4), 534-540. ttps://doi.org/10.1123/ijspp.2019-0320

Vannuccini, S., Fondelli, F., Clemenza, S. *et al.* Dysmenorrhea and Heavy Menstrual Bleeding in Elite Female Athletes: Quality of Life and Perceived Stress. *Reprod. Sci.* 27, 888–894 (2020). https://doi.org/10.1007/s43032-019-00092-7

Vitale, K. C., Owens, R., Hopkins, S. R., & Malhotra, A. (2019). Sleep hygiene for optimizing recovery in athletes: review and recommendations. International journal of sports medicine, 40(08), 535-543. 10.1055/a-0905-3103

Whyte, G. P., George, K., Shave, R., Middleton, N., & Nevill, A. M. (2008). Training induced changes in maximum heart rate. *International journal of sports medicine*, *29*(02), 129-133. 10.1055/s-2007-965783

Wiecek, M., Szymura, J., Maciejczyk, M., Cempla, J., & Szygula, Z. (2016). Effect of sex and menstrual cycle in women on starting speed, anaerobic endurance and muscle power. *Acta Physiologica Hungarica*, *103*(1), 127-132. https://doi.org/10.1556/036.103.2016.1.13

Worsley, R., Davis, S. R., Gavrilidis, E., Gibbs, Z., Lee, S., Burger, H., & Kulkarni, J. (2012). Hormonal therapies for new onset and relapsed depression during perimenopause. *Maturitas*, *73*(2), 127-133. https://doi.org/10.1016/j.maturitas.2012.06.011

Wright Jr, K. P., Hull, J. T., & Czeisler, C. A. (2002). Relationship between alertness, performance, and body temperature in humans. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*. https://doi.org/10.1152/ajpregu.00205.2002

Wright, K. P., & Badia, P. (1999). Effects of menstrual cycle phase and oral contraceptives on alertness, cognitive performance, and circadian rhythms during sleep deprivation. *Behavioural Brain Research*, *103*(2), 185–194. https://doi.org/10.1016/S0166-4328(99)00042-X

Ziomkiewicz, A., Pawlowski, B., Ellison, P.T., Lipson, S.F., Thune, I., Jasienska, G. (2012). Higher luteal progesterone is associated with low levels of premenstrual aggressive behaviour and fatigue. *Biol Psychol.* 91(3), 376–82. https://doi.org/10.1016/j.biopsycho.2012.08.001

Chapter 7: Appendices

Appendix 1: Participant Information Sheet

My name is Robyn Aitkenhead, and I am a postgraduate student conducting a masters by research (MRes). I am obligated to undertake a research project. The title of my project is: **the influence of menstruation on training schedules in female mountain bike, road and cyclocross athletes**.

This study will investigate if different phases of the menstrual cycle influences training schedules, sleep quality and mood in female mountain bike, road and cyclocross athletes. Performance based research in females is lacking due to complexity of their physiology and endocrine system, with many following training schedules that have been research only in male counterparts. This is the first study of this kind and we hope that it will provide valuable insight into current and future practice. This research is critical to help drive future research in female athlete training.

We are looking for volunteers to participate in the project. To participate you must be a female aged 18-40, free from injury and competing at least national level in in at least one mountain bike disciplines (e.g. cross country (XC), trail, downhill, enduro, marathon and/or freeride) and train at minimum of 4 times per week. (For enduro cyclists only); to compete in an enduro race in the enduro world series. (For all other disciplines); must be an expert, senior, master or elite category Contraceptive use and menstrual cycle history will be accounted for but will not impact inclusion in the study.

If you agree to be part of this study, you will be required to commit to 3 months of contact. Prior to starting the study, you'll will record demographic information including demographic information, menstrual cycle and training history. You will also complete a perceived stress scale, morning/evening questionnaire, low energy availability in female's questionnaire (LEAF –Q) to measure relative energy deficiency (RED-s). In addition, if cold or flu symptoms develop, you will complete a Jackson common cold questionnaire daily, until symptoms pass.

Within the 3 months you will be requested to provide daily symptom tracking using an app named 'Clue'. This provides users the ability to monitor menstrual cycle and symptoms. In line with GDPR, the clue app will not provide any personal data (name, email address), personal health or menstrual cycle data to any third-party services. However, may use a third-party tool to improve the quality of app and website services. This last update of private policy was 1st December 2020. The app is free to download and you will not need to pay for anything towards the app. Information can be downloaded and exported by the participant to the researcher on a weekly basis.

Daily temperature and body mass measurements upon wakening will be requested, as well as daily Likert scales to measure arousal, alertness and perceived sleep quality. This will be recording in your training notes of your preferred GPS system (e.g. Garmin Connect, Polar, Strava, Training Peaks, Wahoo). With coach and athlete approval, we require 3 months training and performance data and sleep data where possible.

All data and information will be anonymised, your name will be replaced with a participant number or a pseudonym, and it will not be possible for you to be identified in any reporting of the data gathered. All data collected will be stored on a pc and a flash drive that are password protected to which only the researcher and supervisor have access. Any data which cannot be stored under password protection will be shredded and destroyed. The data will be kept until the end of the examination process, following which all data that could identify you will be destroyed following the Edinburgh Napier University guidelines.

If you have read and understood this information sheet and have had, any questions answered and would like to participant in this study, please see content form

Appendix 2: Informed consent form

<u>Edinburgh Napier University Research Consent Form</u>

The influence of menstruation on training schedules in female mountain bike, road and cyclocross athletes

Edinburgh Napier University requires that all persons who participate in research studies give their written consent to do so. Please read the following and sign it if you agree with what it says.

1. I freely and voluntarily consent to be a participant in the research project on the topic of ‘the influence of menstruation on training schedules in female mountain bike athletes’, conducted by Robyn Aitkenhead, who is a postgraduate student at Edinburgh Napier University.
2. The broad goal of this research study is to determine if different phases of the menstrual cycle influences training schedules, sleep quality and mood in female mountain bike athletes. Specifically, I have been asked to take part in this study remotely for a minimum of 3 months. I will provide menstrual cycle and training data for each day.
3. I have been told that my responses will be anonymised. My name will not be linked with the research materials, and I will not be identified or identifiable in any report subsequently produced by the researcher.
4. I also understand that if at any time during the study I feel unable or unwilling to continue, I am free to leave. That is, my participation in this study is completely voluntary, and I may withdraw from it without negative consequences. However, after data has been anonymised or after publication of results it will not be possible for my data to be removed as it would be untraceable at this point.
5. In addition, should I not wish to answer any particular question or questions, I am free to decline.
6. I have been given the opportunity to ask questions regarding the study and my questions have been answered to my satisfaction.
7. I have read and understand the above and consent to participate in this study. Furthermore, I understand that I will be able to keep a copy of the informed consent form for my records.

Participant’s Signature   Date

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researchers Signature

Edinburgh Napier UNIVERSITY

Appendix 3: Privacy Notice for Research Participants

Edinburgh Napier University, as the Data Controller, is providing you with this information in order for us to comply with the General Data Protection Regulation (EU) 2016/679 and Data Protection Act 2018, which require us to tell you what we do with your personal information.

Introduction/Purposes
This privacy notice deals with personal data provided for the purposes of research only.

Edinburgh Napier University ("We") conducts research to the highest standards of research integrity to ensure it is both beneficial (generally) and enriches higher learning. We respect the confidentiality and sensitivity of the personal information that you provide to us, that we get from other organisations, and that we share with other collaborating organisations (such as other Universities or our research funders). We commit to protecting your personal information secure and complying with the legislation.

Research has a special status under Data Protection legislation. Research conducted by our staff and postgraduate research students is defined as making an original contribution to knowledge which is published in order to share that knowledge.

Who is the Data Controller?
The University is usually the Data Controller for research studies. This means that we will decide how your personal information is created, collected, used, shared, archived and deleted (processed). When we do this, we will ensure that we collect only what is necessary for the project and that you have agreed to this. No third party or organisation will be included within this research project

What personal data is collected from research participants?
The specific information that we will collect about you will be listed in the Participant Information Sheet, given to you. This data will include your name, gender, date of birth, contact details, online and location identifiers. It may also include sensitive (special category) data, such as your ethnicity, sexual orientation, gender identity, biometric or genetic data and details about your health. Data collected should only be that which is appropriate and necessary for the specific research project being conducted.

Who is research data shared with?
Your personal information will be kept confidential at all times and researchers are required to pseudonymise/codify (remove any information which can identify

you such as your name and replace this with a unique code or key), de-identify (anonymise), or delete it as soon as possible.
Your personal information as well as any de-identified information may be shared with:

- The research project team who are authorised to work on the project and access the information - this may include University employees and authorised collaborators at other organisations.
- Where a student is undertaking the research, the data may be shared with their supervisors.
- Auditors, where research audits require access to the data.
- Where there are complaints or data subject rights requests Governance Services, the Research and Innovation Office, Ethics Committee members, appointed investigators, etc. may need access to the data.

If researchers need to share your information with anyone else including anyone outside of the European Economic Area, you will be told who they are and why this is the case in the Participant Information Sheet.

We also sometimes use products or services provided by third parties who carry out a processing on our behalf or provide services or data storage/processing facilities. These third parties are known as data processors and when we use them we have agreements in place to ensure your information is kept safe. This does not always mean that they access your information but if they do this will be outlined in the Participant Information Sheet. As Data Controller, we will always remain responsible for keeping your information safe throughout the research.

We will only keep your personal information for as long as necessary to complete the aims of the research. However, some personal information (including signed records of consent) will be kept for a minimum amount of time as required by external funders or our policies and procedures.

When using research repositories, researchers are often required to upload their supporting or underlying data which may be identifiable or sensitive. The repositories have technical controls in place to ensure that only authorised individuals can access the information.

The University undertakes to maintain your information securely and will restrict access to employees, our professional advisers, authorised agents and contractors on a strictly need to know basis. We will only disclose your data to external third parties (other than any specified above) where there is a justified purpose and we:
Have your consent
Are required to do so under a statutory or legal obligation

Are permitted to do so by Data Protection legislation.

The University NEVER sells personal data to third parties. Your anonymised data will be included in the resulting research output and may form part of a research publication, conference presentation or public talk.

What is the legal basis for processing?
Data protection law requires us to have a valid legal reason to process and use personal data about you. This is often called a 'legal basis'. GDPR requires us to be explicit with you about the legal basis upon which we rely in order to process information about you.

For research the legal basis the University relies on is Article 6(1)(e): for the performance of a task carried out in the public interest or in the exercise of the official authority vested in the controller, namely the University's Statutory Instruments: "for the objects of …carrying out research".

Where sensitive personal data is being processed the additional bases from Article 9(2)(j) is: *"the processing is necessary for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes… which shall be proportionate to the aim pursued, respect the essence of the right to data protection and provide for suitable and specific measures to safeguard the fundamental rights and the interests of the data subject".*

When research involves criminal convictions, the University relies on the legal basis as provided for by Schedule 1, Part 1, Section 4 of the Data Protection Act 2018, and researchers must ensure that special safeguards, as required by the legislation, are in place.

Where we need to rely on a different legal reason, this will be listed in the Participant Information Sheet provided to you. In clinical trials or medical studies, for example, we may use the following reason:

GDPR Article 9(2)(h): *"Processing is necessary for the purposes of preventive or occupational medicine, for the assessment of the working capacity of the employee, medical diagnosis, the provision of health or social care or treatment or the management of health or social care systems and services on the basis of Union or Member State law or pursuant to contract with a health professional and subject to the conditions and safeguards".*

Where anonymous data is provided by other organisations for research purposes this is not covered by data protection legislation, however researchers will submit the data to rigorous checks to ensure it can never be reconstituted with other data to identify individuals. Due care will also be taken with research outputs to ensure they are disaggregated to the extent possible to ensure anonymity.

The personal data collected at the initial questionnaire will be the only personal data collected. This is important because it is used to understand the different circumstances each athlete is in, including menstrual cycle status, their biometrics and any health data to understand why this may influence their menstrual cycle.
Participants will be provided a codification (example 001) and will use this in the Qualtrics questionnaire.

This code will anonymize the participant. A separate password protected document will be stored on the V:drive which will have the participant codes and participant names and only lead investigator (Robyn Aitkenhead) will have access to this.

How are we collecting this information?
Researchers will collect participant information online/electronically.

How long is your information kept?
Raw data will be kept for 3 months, until the thesis is submitted (February 2022). Analysed data will be stored on a secure university drive for 10 years and consent forms for 6 years. For some research projects, your de-identified or pseudonymised information will be kept after the project has ended, placed into a data repository/online archive for sharing with other researchers or used in future research. If the researchers would like to do this with your information you will be told in the Participant Information Sheet. Further information can be found online at:
https://staff.napier.ac.uk/services/governancecompliance/governance/records/Pages/RecordsRetentionSchedules.aspx

How secure is your information?
For services provided locally by Information Services, information is stored on servers located in secure University data centres. These data centres are resilient and feature access controls, environmental monitoring, backup power supplies and redundant hardware. Information on these servers is backed up regularly. The University has various data protection and information security policies and procedures to ensure that appropriate organisational and technical measures are in place to protect the privacy of your personal data. The University makes use of a number of third party, including “cloud”, services for information storage and processing. Through procurement and contract management procedures the University ensures that these services have appropriate organisational and technical measures to comply with data protection legislation. The University is Cyber Essentials Plus accredited.

Where researchers use systems and services not provided as standard through Information Services they are required to ensure that Data Protection and Information Services checks have been completed and approved by

Governance Services and Information Services, which are likely to include Privacy Impact Assessments, and that the necessary Data Sharing/Processing Agreements are in place. Researchers must provide assurances in their Participant Information Sheets as to the local measures they are taking e.g. data is pseudonymised/anonymised, password protected/access restricted/under lock and key, kept in University/University approved systems, etc.

Who keeps your information updated?
Researchers rely on participants to advise them of any personal data which needs to be updated.

Will your information be used for any automated decision making or profiling?
The researcher/s will advise in the Participant Information. If the answer is 'yes' meaningful information about the logic involved, significance and envisaged consequences of such processing to must be provided.

Is information transferred to a third country? Outside the EEA and not included in the adequate countries list.
The researcher/s will advise in the Participant Information.
Safeguards
Under Data Protection legislation we must have special safeguards in place to help protect your rights and freedoms when using your personal information and these are:
- Policies and procedures that tell our staff and students how to collect and use your information safely.
- Training which ensures our staff and students understand the importance of data protection and how to protect your data.
- Security standards and technical measures that ensure your information is stored safely and securely.
- All research projects involving personal data are scrutinised and approved by a research ethics committee in line with University policies and procedures.
- Contracts with companies or individuals not associated with the University have confidentiality clauses to set out each party's responsibilities for protecting your information.
- We carry out data protection impact assessments to ensure that your privacy, rights as an individual or freedoms are not affected.
- If we use collaborators outside of Europe, we will ensure that they have adequate data protection laws or are part of privacy and security schemes such as the privacy shield in the US.

In addition to the above University safeguards the Data Protection legislation also requires us to meet the following standards when we conduct research with your personal information:

(a) the research will not cause damage or distress to someone (e.g., physical harm, financial loss or psychological pain).
(b) the research is not carried out in order to do or decide something in relation to an individual person, unless the processing is for medical research approved by a research ethics committee. (c) the Data Controller has technical and organisational safeguards in place (e.g. appropriate staff training and security measures).
(d) if processing a special category of data, this must be subject to a further public interest test to make sure this particularly sensitive information is required to meet the research objectives.

What are your Rights?
By law you have rights in relation to the personal information we hold about you. These include the right to:
See the information/receive a copy of the information;
Correct any inaccurate information;
Have any information deleted;
Limit or raise concerns to our processing of the information; Move your information ("portability").

These rights only apply to your information before it is anonymised, as once this happens we can no longer identify your specific information. Sometimes your rights may be limited if it would prevent or delay the research. If this happens you will be informed and have the right to complain about this to the Information Commissioner. If you have any questions about how your personal information is used, or wish to exercise any of your rights, please consult the University's data protection webpages or contact the University's Data Protection Officer at dataprotection@napier.ac.uk

If you are not happy with the way your information is being handled, or with the response received from us, you have the right to lodge a complaint with the Information Commissioner's Office at Wycliffe House, Water Lane, Wilmslow, SK9 5AF (https://ico.org.uk/).

For more information please see:
https://staff.napier.ac.uk/services/governancecompliance/governance/DataProtection/Pages/default.aspx

Appendix 4: Debrief form

Debrief for Participant

Thankyou for taking part in the study:

'The influence of menstruation on training schedules in female mountain bike, road and cyclocross athletes'

We hope you enjoyed being part of the study and learnt a lot from the experience. This study will hopefully give a better insight into the impact of mensuration on female athletes, specifically mountain bikers, training schedules and performance.

If you wish to find out more about mensuration and female athletes, please visit the links below to find previous research that has been conducted:

1. https://link.springer.com/article/10.1007/s40279-020-01319-3
2. https://link.springer.com/article/10.1007/s40279-020-01317-5

If you have any questions regarding the study or you would like your data to be removed from the study and destroyed please contact the researcher or supervisor for the study. See below for details.

Contact details of the researcher:

Name of main researcher: Robyn Aitkenhead

Email: robyn.aitkenhead@napier.ac.uk

Contact details of the supervisor

Name of supervisor: Dr Lesley Ingram-Sills

Email: L.Ingram-Sills@napier.ac.uk

Appendix 5: Perceived Stress Scale

For each question choose from the following alternatives:
0 - never 1 - almost never 2 - sometimes 3 - fairly often 4 - very often

________ I. In the last month, how often have you been upset because of something that happened unexpectedly?

________ 2. In the last month, how often have you felt that you were unable to control the important things in your life?

________ 3. In the last month, how often have you felt nervous and stressed?

________ 4. In the last month, how often have you felt confident about your ability to handle your personal problems?

________ 5. In the last month, how often have you felt that things were going your way?

________ 6. In the last month, how often have you found that you could not cope with all the things that you had to do?

________ 7. In the last month, how often have you been able to control irritations in your life?

________ 8. In the last month, how often have you felt that you were on top of things?

________ 9. In the last month, how often have you been angered because of things that happened that were outside of your control?

________ 10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

Cohen, S., Kamarck, T., and Mermelstein, R. (1983). A global measure of perceived stress. Journal of Health and Social Behavior, 24, 386-396. http://www.jstor.org/stable/2136404

Appendix 6: Morning or Eveningness Questionnaire

Horne and Ostberg, (1976) Morning or Evening Type Questionnaire

Q1. Considering only your own "feeling best" rhythm, at what time would you get up if you were entirely free to plan your day?

5am – 6:30am

6:30am to 7:45am

7:45am – 9:45am

9:45am – 11am

11am – 12pm

Q2. Considering only your own "feeling best" rhythm, at what time would you go to bed if you were entirely free to plan your evening?

8pm – 9pm

9pm – 10:15pm

10:15pm – 12:30am

12:30am – 1:45am

1:45am – 3am

Q3. If there is a specific time at which you have to get up in the morning, to what extent are you dependant on being woken up by an alarm clock?

Not at all dependent

Slightly dependent

Fairly dependent

Very dependent

Q4. Assuming adequate environmental conditions, how easy do you find getting up in the mornings?

Not at all easy

Not very easy

Fairly easy

Very easy

Q5. How alert do you feel during the first half hour after having woken in the mornings?

Not at all alert

Slightly alert

Fairly alert

Very alert

Q6. How is your appetite during the first half-hour after having woken in the mornings?

Very poor

Fairly poor

Fairly good

Very good

Q7. During the first half-hour after having woken in the morning, how tired do you feel?

Very tired

Fairly tired

Fairly refreshed

Very refreshed

Q8. When you have no commitments the next day, at what time do you go to bed compared to your usual bedtime?

Seldom or never later

Less than one hour later

1 – 2 hours later

More than two hours later

Q9. You have decided to engage in some physical exercise. A friend suggests that you do this one hour twice a week and the best time for him is between 7am – 8am. Bearing in mind nothing else but your own "feeling best" rhythm, how do you think you would perform?

Would be on good form

Would be on reasonable form

Would find it difficult

Would find it very difficult

Q10. At what time in the evening do you feel tired and as a result in need for sleep?

8pm – 9pm

9pm – 10:15pm

10:15pm – 12:45am

12:45am – 2am

2am – 3pm

Q11. You wish to be at your peak performance for a test which you know is going to be mentally exhausting and lasting for two hours. You are entirely free to plan your day and considering only your own "feeling best" rhythm, which one of the four test times would you choose?

8am – 10am

11am – 1pm

3pm – 5pm

7pm – 9pm

Q12. If you went to bed at 11pm, at what level of tiredness would you be?

Not at all tired

A little tired

Fairly tired

Very tired

Q13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following events are you most likely to experience?

Will wake up at usual time and will not fall asleep

Will wake up at usual time and will doze thereafter

Will wake up at usual time but will fall asleep again

Will not wake up until later than usual

Q14. One night you have to remain awake between 4am – 6am in order to carry out a night watch. You have no commitments the next day. Which one of the following alternatives will suit you best?

Would not got to bed until watch was over

Would take a nap before and sleep after

Would take a good sleep before and nap after

Would take all sleep before watch

Q15. You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your own "feeling best" rhythm, which one of the following times would you choose?

8am – 10am

11am – 1pm

3pm – 5pm

7pm – 9pm

Q16. You have decided to engage in hard physical exercise. A friend suggests that you do this for one hour twice a week and the best time for him is between 10pm – 11pm. Bearing in mind nothing else but your own "feeling best" rhythm, how well do you think you would perform?

Would be on good form

Would be on reasonable form

Would find it difficult

Would find it very difficult

Q17. Suppose that you can choose your own work hours. Assume that you worked a five hour day (including breaks) and that your job was interesting and paid by results. What time would you finish?

5am – 8am

9am

10am – 2pm

3pm – 5pm

6pm – 4am

Q18. At what time of the day do you think that you reach your "feeling best" peak?

10pm – 4am

5am – 7am

8am – 9am

10am – 4pm

5pm – 9pm

Q19. One hears about “morning” and “evening” types of people. Which one of these types do you consider yourself to be?

Definitely a morning type
Rather more a morning than an evening type
Rather more an evening than a morning type
Definitely an evening type

Appendix 7: The low energy availability in females questionnaire (LEAF-Q)

1. Injuries
A: Have you had absences from your training, or participation in competitions during the last year due

No not at all Yes, once or twice Yes, three or four times Yes, five or more times

A1: If yes, for how many days absence from training or participation in competition due to injuries have you had in the last year?

1-7 days 8-14 days 15-21 days 22 days or more

A2: If yes, what kind of injuries have you had in the last year?

2. Gastro intestinal function

A: Do you feel gaseous or bloated in the abdomen, also when you do not have your period?

Yes, several times a day Yes, several times a week Yes, once or twice a week or more seldom Rarely or never

B: Do you get cramps or stomach ache which cannot be related to your menstruation?

Yes, several times a day Yes, several times a week Yes, once or twice a week or more seldom Rarely or never

C: How often do you have bowel movements on average?

Several times a day Once a day Every second day Twice a week Once a week or more rarely

D: How would you describe your normal stool?

Normal (soft) Diarrhoea-like (watery) Hard and dry

3. Menstrual function and use of contraceptives

3.1 Contraceptives

A: Do you use oral contraceptives?

Yes No

A1: If yes, why do you use oral contraceptives?

Contraception Reduction of menstruation pains Reduction of bleeding To regulate the menstrual cycle in relation to performances etc Otherwise menstruation stops

A2: If no, have you used oral contraceptives earlier?

Yes No

A2:1 If yes, when and for how long? _________

B Do you use any other kind of hormonal contraceptives? (e.g. hormonal implant or coil)

Yes No

B1: If yes, what kind?
Hormonal patches Hormonal ring Hormonal coil Hormonal implant Other __________

3.2 Menstrual function

A: How old were when you had your first period?

11 years or younger 12-14 years 15 years or older I don't remember I have never menstruated (If you have answered "I have never menstruated" there are no further questions to answer)

B: Did your first menstruation come naturally (by itself)?

Yes No I don't remember

B1: If no, what kind of treatment was used to start your menstrual cycle?

Hormonal treatment Weight gain Reduced amount of exercise Other

C: Do you have normal menstruation?
Yes No (go to question C6) I don't know (go to question C6)

C1: If yes, when was your last period?
0-4 weeks ago 1-2 months ago 3-4 months ago 5 months ago or more

C2: If yes, are your periods regular? (Every 28th to 34th day)

Yes, most of the time No, mostly not

C3: If yes, for how many days do you normally bleed?
1-2 days 3-4 days 5-6 days 7-8 days 9 days or more

C4: If yes, have you ever had problems with heavy menstrual bleeding?

Yes No

C5: If yes, how many periods have you had during the last year?
12 or more 9-11 6-8 3-5 0-2

3.2 Menstrual Cycle

C6: If no or "I don't remember", when did you have your last period?
2-3 months ago 4-5 months ago 6 months ago or more

I'm pregnant and therefore do not menstruate

D: Have your periods ever stopped for 3 consecutive months or longer (besides pregnancy)?
No, never Yes, it has happened before Yes, that's the situation now

E: Do you experience that your menstruation changes when you increase your exercise intensity, frequency or duration?

Yes No

E1: If yes, how? (Check one or more options)

I bleed less I bleed fewer days I bleed more My menstruations stops

I bleed more days

Appendix 8: Demographic Information

Age (y) _____ Height (m) _____ Body Mass (kg) ______ Gender ________

Ethnicity ________ Current Location (e.g. Scotland) ________

Age at menarche (y) ______ Gynaecological age (y) _____

Occupation ____________

Duration competing at current level (y) _________

Number of training session per week _________

Average training session duration (mins) _________

Total weekly training duration (mins) _______

Main mountain bike discipline ________

Any other disciplines ___________

Number of competitions in the last 6 months ________

Predicted number of competitions in the next 6 months _________

Do you take part in any other sport? ________

GPS system used (e.g. Garmin/polar/wahoo)? ______________

Menstrual cycle history

Have you been diagnosed with Polycystic Ovary Syndrome (PCOS)? ________

If your periods stopped because of medication, which medication were you taking? Medication name: _____________________________________

Have you ever been prescribed with hormone replacement therapy (HRT)? ________

How heavy is your menstrual cycle flow? Light, Moderate, Heavy

In the last 3 months, have you taken pain-killers for the pain prescribed by your doctor? ________

In the last 3 months, have you taken pain-killers for the pain bought over the counter? ________

Have you ever seen a medical practitioner about problems associated with your period? ________

Appendix 9: Jackson common cold questionnaire

Report the following symptoms based on a score of severity points (0 = absent, 1 = mild, 2 = moderate, 3 = severe)

1. Sneezing
2. Nasal obstruction
3. Nasal discharge
4. Sore throat
5. Cough
6. Headache
7. Chilliness
8. Malaise

A Jackson score is based on a simple sum of severity points (0 = absent, 1 = mild, 2 = moderate, 3 = severe) for eight cold symptoms: sneezing, nasal obstruction, nasal discharge, sore throat, cough, headache, chilliness, and malaise.
Approximately 16 h before ovulation, LH peaks; the presence of LH in urine is a reliable marker of ovulation.

Appendix 10: Arousal, alertness and sleep quality questionnaire

Read the statement below and ring the number that best describes how you feel at the moment.

1. Feeling active and vital, alert and awake.
2. Functioning at a high level but not at peak. Able to concentrate.
3. Relaxed, awake but not at full alertness. Responsive.
4. A little foggy, not at peak, let down.
5. Fogginess, beginning to lose interest in remaining awake, slowed down.
6. Sleepiness, prefer to be lying down, fighting sleep, woozy.
7. Almost in reverie, sleep onset soon, lost struggle to remain awake.

Place an "x" on the scale below to describe the above statements. A mark to the extreme left of the line indicates 'as tried as I've ever felt', the extreme right indicates ' as alert as I've ever felt' and the intermediate position indicates intermediate feelings of alertness.

¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦

0 1 2 3 4 5 6 7 8 9 10

8. "How would you evaluate the quality of your sleep last night?"

Place an "x" on the scale below to describe your sleep quality. A mark to the extreme left indicates sleep quality as 'very bad' and extreme right indicates sleep quality as 'excellent' and the intermediate position indicates normal sleep quality.

¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦ ---- ¦

0 1 2 3 4 5 6 7 8 9 10

Appendix 11: Post study interview

Post research interview questions:

Hi and thanks once more for participating in the current study. Since this data collection occurred during a pandemic, we would like to ask you a few questions relating to that in order to capture any important information. You do not need to answer the questions if you don't want to and you can stop the interview at any time. Do you consent to this interview taking place?

1. First of all, we would just like to explore if any changes occurred in your training schedule due to the COVID-19 pandemic?
2. If so, what did this look like?
3. Looking ahead would you keep any of the alterations for next years training schedule?
4. Did your race season differ in any way when comparing it to seasons when covid was not around?
5. Can you provide details on the changes?
6. How have you felt whilst racing and competing during a pandemic?
7. Have you noticed a change in your menstrual cycle during this time?
8. Can you give an example here?
9. Do you think we could have made any improvements to the current study?
10. If so in what way?

Thank you for your time.

Appendix 12: Instructions for day to start ovulation strips

(*Home Health (UK),* Ovulation Test Strips 20mIU/mL Tests 3.5mm Wide One Step, 10 Tests*,* https://homehealth-uk.com/wp/wp-content/uploads/IND-One-Step-LH-Strip-ver-1.3-02.06.2016.pdf)

Your Cycle Length	Start to test on
21 days	Day 6
22 days	Day 6
23 days	Day 7
24 days	Day 7
25 days	Day 8
26 days	Day 9
27 days	Day 10
28 days	Day 11
29 days	Day 12
30 days	Day 13
31 days	Day 14
32 days	Day 15
33 days	Day 16
34 days	Day 17
35 days	Day 18
36 days	Day 19
37 days	Day 20
38 days	Day 21
39 days	Day 22
40 days	Day 23