# Effects of the Menstrual Cycle and Mitigating its Impact in Resistance-Trained Women

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# Abstract

Women's participation in exercise and sport has increased, yet there is less research on female exercisers than males. The primary physiological difference between males and females is the MC, which is the regular hormonal cycle in reproductive-age women marked by sex hormone changes of up to 100% in a single day. MC symptoms affect over 90% of females, and the literature suggests that MC hormonal changes may affect RT performance. However, many direct studies observe no apparent effect on performance attributable to specific MC hormones. Therefore, this thesis aimed to add to the limited literature on normative MC characteristics in RT females to elucidate how the MC affects their performance and to investigate a novel method to reduce MC symptoms.

First, RT females were surveyed regarding their MC to determine its characteristics, assess the prevalence of MC symptoms, and uncover its perceived effects on RT performance. In the 809 respondents, MC symptoms were highly prevalent (92%) and most (59%) perceived that their MC negatively affected performance. Further analysis examined the relationship between diet, body image, and eating disorders among RT women. Mental health appears to be impacted by the MC, and is an important consideration for RT women that should be openly discussed and addressed in sport settings.

Building on this survey data with objective methods, a monitoring study was conducted measuring MC characteristics and symptoms in conjunction with well-being and perceived performance in a cohort of RT females for three MCs. Notably, there was a high prevalence of cycle irregularity, and inter- and intra-individual variation in the MC within this cohort. Further, there were distinct temporal patterns, such as a significantly

higher probability of poorer mental health during the beginning and end of the MC, lower estimated one-repetition maximums at the end of the MC, and lower perceived recovery status scores at both the beginning and end of the MC. These data demonstrate the importance of accounting for inter- and intra-individual MC variation cycle-to-cycle, the commonality of irregular cycles, and patterns of MC symptoms in RT women.

Having established the commonality of physiological and psychological MC-related symptoms in RT women, the final study investigated the influence of a mindfulness-based yoga protocol on MC symptoms, measures of well-being, and performance in a cohort of RT women. In a crossover design, RT women engaged in a daily at-home yoga practice for one MC. The yoga intervention was significantly associated with lower levels of bloating, low back pain, menstrual cramps, and stress. Furthermore, perceived performance was significantly more stable across the MC when daily at-home yoga was performed. Daily, at-home, mindfulness-based yoga may reduce MC symptoms in RT women and warrants consideration and further study.

Further research should investigate the array of MC experiences, how mental health effects are associated with the MC, and establish additional methods for effectively reducing MC symptoms in athletic populations. Based on the findings within this thesis, MC concerns should be treated with an individualised approach due to the considerable amount of individual variability.

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# List of commonly used abbreviations

BBT: basal body temperature

BID: body image dissatisfaction

ED: eating disorder

FSH: follicle-stimulating hormone

GnRH: gonadotropin-releasing hormone

HC: hormonal contraceptive

LH: luteinising hormone

MC: menstrual cycle

1RM: one-repetition maximum

PCOS: polycystic ovary syndrome

PD: Primary dysmenorrhea

PMS: premenstrual syndrome

PRS: perceived recovery status

RHR: resting heart rate

RED-S: Relative Energy Deficiency in Sport

RIR: repetitions in reserve

RPE: rating of perceived exertion

sRPE: session rating of perceived exertion

RT: resistance-trained

SD: standard deviation

# Attestation of authorship

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

Kimberly SantaBarbara

## Co-authored works

SantaBarbara, KL, Helms, ER, Armour, MJ, and Harris, NK
Menstrual cycle characteristics, hormonal contraceptive use, and perceptions of related effects in resistance-trained athletes. *International Journal of Sport Science & Coaching*

SantaBarbara, KL, Helms, ER, and Harris, NK
The associations between calorie tracking, body image dissatisfaction, eating disorders, and menstrual cycle characteristics in resistance-trained athletes. *Journal of the International Society of Sports Nutrition (In review)*

SantaBarbara, KL, Helms, ER, Stewart, TI, Armour, MJ, and Harris, NK
Menstrual cycle patterns and their relationship with measures of well-being and perceived performance metrics in competitive and recreational resistance-trained athletes. *Journal of Sports Medicine and Physical Fitness*

SantaBarbara, KL, Helms, ER, Stewart, TI, Armour, MJ, and Harris, NK
A randomized crossover trial on the influence of a daily mindfulness yoga practice on menstrual cycle symptoms, measures of well-being, and training perception in athletic women. *International Journal of Yoga Therapy (In review)*

**We, the undersigned, hereby agree to the participation of the chapters identified above.**

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## Ethics approval

The Auckland University of Technology Ethics Committee (AUTEC) granted ethical approval for the thesis research on:

- 5 March 2021 AUTEC reference number 21/22 (Chapters 3 and 4) (Appendix A)
- 17 June 2021 AUTEC reference number 21/22 (Chapters 5 and 6) (Appendix B)
- 11 November 2021 Amendment AUTEC reference number 21/22 (Chapter 6) (Appendix C)

# Chapter 1 Introduction

## Section 1: Background and rationale

Medical and health-related research has largely under-represented female participants and often generalised research on males to the entire population, which has disadvantaged women's health and well-being [1,2]. Exercise science is no exception: although women have been actively participating in elite-level competitive sports for decades, and female recreational exercise and sport participation has increased in recent years, there is still less published research on female exercisers than their male counterparts [2,3]. The primary cited physiological difference between males and females of reproductive age is the MC and the related hormonal changes, which are seen as complex and confounding factors leading to the exclusion of females in many areas of research [3,4]. The MC is a regularly occurring hormonal cycle in reproductive-age women, which leads to changes in female sex hormones by as much as 100% over the course of one day [5]. MC symptoms can range from mild to debilitating and, for some, cause disruptions to work, education, activities of daily living, and exercise [6–8]. For many women, MC symptoms occur in most cycles and do not appear to improve with age, causing an approximately monthly disruption over many decades [9]. The effects of MC symptoms should not be overlooked and warrant further research, as symptoms appear to affect over 90% of females [6,10–12]. MC symptoms can reduce exercise and sports participation, training capacity, and workout adherence [11,12].

Multiple literature reviews have identified that the MC hormonal changes and the unique phases of the MC may affect resistance training performance [13–15], but other reviews have concluded that there is no apparent effect that is attributable to unique MC phases [4,16] or that results are inconclusive regarding any definitive MC hormone effects on sports performance [17]. This lack of clarity has been attributed to methodological design issues in MC-based research [10,13,18] and a lack of precise normative data on typical MC characteristics and symptoms in the athletic population [2,3].

This dearth of research focusing on female participants is seen across all sports disciplines, but none more so than in the areas of resistance training and strength athletes. More data is needed specifically on normative MC characteristics and symptoms in athletic females since previous research has shown a higher frequency of irregular MC in the exercising population than in the general population [19]. The psychological perception of the effects of the MC on sports performance is equally important to uncover because psychological outlook and one's self-efficacy can influence sport participation [20]. Unravelling the psychological effects of the MC and the perception of MC effects on performance are important keys to clarifying the discrepancies with objective outcome measures on MC performance effects.

Healthcare providers often recommend analgesics and HCs for MC symptom mitigation. However, neither of these options appear to relieve all MC symptoms and, at times, may cause subsequent side effects, leaving women looking for other possibilities [10,21,22] . Since MC symptoms can have debilitating effects, females need more methods to mitigate these symptoms – both physiological and psychological. Perhaps unsurprisingly, given the physiological and psychological nature of symptoms, previous research has shown the potential benefits of mind-body interventions such as yoga for MC symptom management [23–25]. However, further research is needed to explore the effects in an already athletic population. Therefore, the following research will specifically target RT women, first to better understand their characteristics and experiences as they relate to the MC and its impact on performance and well-being, and then to experimentally intervene with a yoga-based mind-body intervention. Doing so will help to increase female sports and exercise participation, expand the body of knowledge on female athlete physiology and psychology, and help to advance females in sports performance.

## Section 2: Purpose of the research

The overarching aim of this thesis was to increase the body of knowledge on MCs of females who participate in resistance training and specifically answer the questions:

1. What are the normative MC characteristics and symptoms in RT women, and do they differ from the general population?
    a. Do MC characteristics and symptoms differ between RT recreational athletes and competitive athletes?
    b. How do MC measures of well-being and perception of training difficulty change across the MC in RT women?
    c. Are MC characteristics or symptoms connected to issues like body image dissatisfaction, calorie tracking habits, or eating disorders in RT women?
2. What are the perceived effects of the MC on performance and training in RT women?
    a. Do these perceived MC effects differ between the recreational RT women and competitive strength athletes?
3. Does a short daily mindfulness-based yoga practice influence MC symptoms, well-being measures, or perceived training performance across the MC in RT women?

## Section 3: Significance of the thesis

Due to the lack of research on females in exercise science, developing this area is essential for female athletic growth [2,3]. An analysis of female participants in exercise science research showed, on average, 35% of studies included female participants, demonstrating that females were underrepresented across all journals at the time. The growing body of literature on this topic has shown that data from male subjects cannot always be applied to women because there are distinct sex differences in body functions and physiological responses that must be considered [3]. Therefore, substantially more research using high-quality methodology looking at females exclusively is needed to increase our understanding of the female body and its response to exercise. This thesis utilised the most up-to-date methodological recommendations [18,26] to accurately obtain data about normative MC characteristics and symptoms in the RT women.

The role of muscle mass in force production is essential for all human performance [27], but plays a vital role in female health for multiple reasons. For example, in young women and girls, there appears to be an increased risk of anterior cruciate ligament injuries compared to their male counterparts [28]. There are many theories about why this injury occurs more frequently in women than men, but developing quadriceps strength appears to reduce risk and similar injury occurrences [28]. Since the MC occurs approximately 451 times in a female's lifetime [29], understanding all details of this hormonal cycle and how it may affect strength training and performance is imperative. Increasing the body of knowledge about women in sports and specifically muscular development will improve women's health overall. This thesis adds to the existing data on women in sport science, specifically in the under-researched area of resistance training.

## Section 4: Structure of the thesis

This thesis is presented inclusive of journal-style articles (known by AUT as 'Format 2'), aside from the introduction, literature review, and the discussion chapters. It is organised into three sections (Figure 1-1). The first section introduces the thesis (Chapter 1) and reviews the current related literature on the MC in sports, HC use, and MC perceptions among athletes (Chapter 2). The second section presents data collected from a comprehensive cross-sectional survey of RT females which presents perceived data about MC characteristics, symptoms, and effects (Chapter 3), and the relationship between MC characteristics, calorie tracking, body image, and eating disorders (Chapter 4). The third section presents the measured MC characteristics and symptoms in a cohort of RT females and changes in measures of well-being and perceived performance metrics across and in relation to the MC and its phases (Chapter 5). This section of the thesis also investigates the effects of a mind-body yoga intervention on MC symptoms, measures of well-being, and perceived performance metrics in a cohort of RT women (Chapter 6) and concludes with a general discussion of this thesis and recommendations for future related research (Chapter 7).

Chapters 3, 4, 5 and 6 are in various stages of publication in peer-reviewed journals. Chapter 3 is published in the International Journal of Sports Science & Coaching, Chapter 4 is under review by the Journal of the International Society of Sports Nutrition, Chapter 5 is published in the Journal of Sports Medicine and Physical Fitness, and Chapter 6 is under review by the International Journal of Yoga Therapy. These chapters are therefore presented in the format of the respective journal. Some inherent repetition is therefore present between the chapters representing journal articles, and the final discussion chapter.

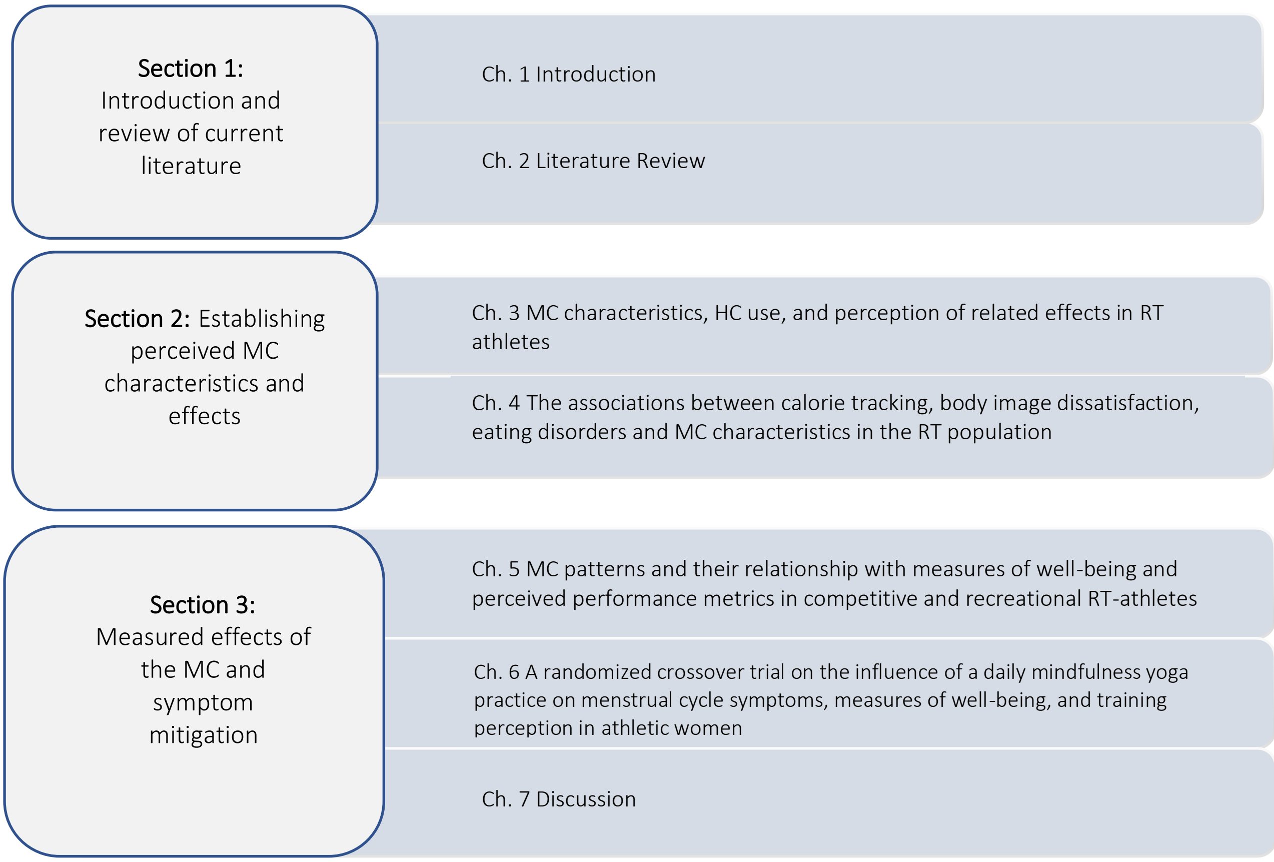


Figure 1-1 Thesis structure

# Chapter 2 Literature review

## Section 1: Introduction

With the increase in female sports participation in recent decades, many athletes and coaches theorise that the MC, as well as HC use, may have effects on performance and recovery [11,12,15,30,31]. The MC is a hormonal process that causes notable fluctuations in a collection of reproductive hormones in preparation for the body's natural reproductive efforts during a female's fertile years [10,32,33]. Each phase of the MC is characterised by the dominant hormone and the hormonal action in the body during that phase [18,32]. The MC hormones that rise and fall throughout each cycle are released into the bloodstream and have a primary effect on reproductive organs, but they also have secondary functions and impact other tissues throughout the body, including the brain [31,34]. These secondary physical and psychological effects of MC hormones have prompted interest in understanding how MC hormonal fluctuations may impair or enhance athletic performance [10,35]. Resistance training is widely used by athletes in many sports to supplement their sport-specific training [36], and is the primary training modality for those that compete in strength and power sports. It has been proposed that attention to the phasic nature of the MC should be considered within resistance training programming and testing due to the potential effects of the MC [37–39].

There is a wide variety of physical and psychological symptoms related to the MC. Physical MC symptoms that impact sports performance, such as uterine cramp-based pain or dysmenorrhea, are common among athletes [12,40]. Psychological MC symptoms, such as mood changes, are potentially more common than physical symptoms alone, and are seen in 90% of exercising females [11]. Additionally, disordered eating patterns among female athletes may lead to MC irregularity and conditions like RED-S, which is a growing concern in female athletes [41].

It is difficult to draw firm conclusions on the effects of the MC or HCs on athletic performance because this area is under-researched and contains many studies of poor methodological quality [4,13,42]. Furthermore, due in part to the lack of research but also the vast range of MC symptoms, there are currently few well-proven remedies for athletes to manage MC symptoms and cycle irregularities. Therefore, to better elucidate the existing data, this review will describe the hormonal process of the MC, outline the existing research on the effects of the MC on athletic performance among RT female athletes, highlight current options for symptom mitigation, and propose further research into modalities to potentially reduce MC symptoms among athletes.

## Section 1.1: Narrative review process and methods

This narrative review discusses the MC and its effect on sports performance in RT athletes while also reviewing the relevant literature on MC symptom mitigation. To conduct this review, the following databases were searched: PubMed/MEDLINE, EBSCO, Google Scholar, and Scopus. The initial search used the keywords “female OR women OR woman OR females”, “resistance training OR strength training OR weight training OR resistance exercise”, “menstrual AND cycle OR menstruation OR menses OR hormonal AND cycle OR hormone AND cycle OR hormonal AND contraceptive OR birth control pill”. A secondary search was employed using the terms “menstrual cycle OR menses OR period AND symptoms OR pain” and “treatment OR mitigation OR management” and “athletes OR exercise OR sports OR performance OR training”. Based on the results from the second search, a third search was conducted using the terms “menstrual AND symptoms OR period AND symptoms OR PMS" and "mindfulness OR body awareness OR meditation OR yoga". A final search was conducted using the keywords "low energy availability, OR LEA OR RED-S OR female athlete triad OR body image AND athlete". Additionally, key references listed in relevant articles were also searched and reviewed. The search was conducted in July of 2022 with the criteria of English language peer reviewed studies with an available full text. Articles were chosen for this review based on relevancy and the population studied.

## Section 2: MC hormonal process overview

To understand the effects of the MC on resistance training performance, it is essential to establish the general processes of the MC hormones and their impacts on the body. Fluctuations in natural hormones cause changes in the body in preparation for reproductive efforts. The natural rhythm that stimulates this process is controlled by the hypothalamus-pituitary axis [43,44]. Each phase of the MC is characterised by the dominant hormone during that phase and its action in the body.

The cycle starts in the follicular phase, marked by the initial shedding of the menstrual lining from the previous cycle [5]. The follicular phase is dominated by oestrogen and the preparation of the follicle, which will be primed for release during ovulation. The beginning of the hormonal cycle during the follicular phase is marked by the release of GnRH, which signals the release of FSH from the anterior pituitary gland, which then leads to the release of LH [43,45]. The release of GnRH, FSH, and LH together stimulates further oestrogen production in the ovaries. Oestrogen is continually released throughout the cycle, with marked peaks prior to ovulation and during the middle of the luteal phase. FSH, LH and oestrogen together stimulate the growth of the follicle in the ovary, which, when released, marks the end of the follicular phase [26,45].

The release of the matured egg from the ovary signifies ovulation, and after ovulation has occurred, the next part of the MC begins the luteal phase.

The luteal phase is characterised by the corpus luteum releasing the dominant hormone during this phase, progesterone, from the ruptured follicle, which prepares the body for a potential pregnancy [45,46]. By the mid-luteal phase, circulating oestrogen levels increase 5-fold, compared to the early follicular phase, and progesterone levels by 50-fold as the body continues to prepare the endometrium for implantation [18,34]. If no fertilised egg is detected, the uterus sheds its menstrual lining, thereby ending the luteal phase and starting the cycle over again.

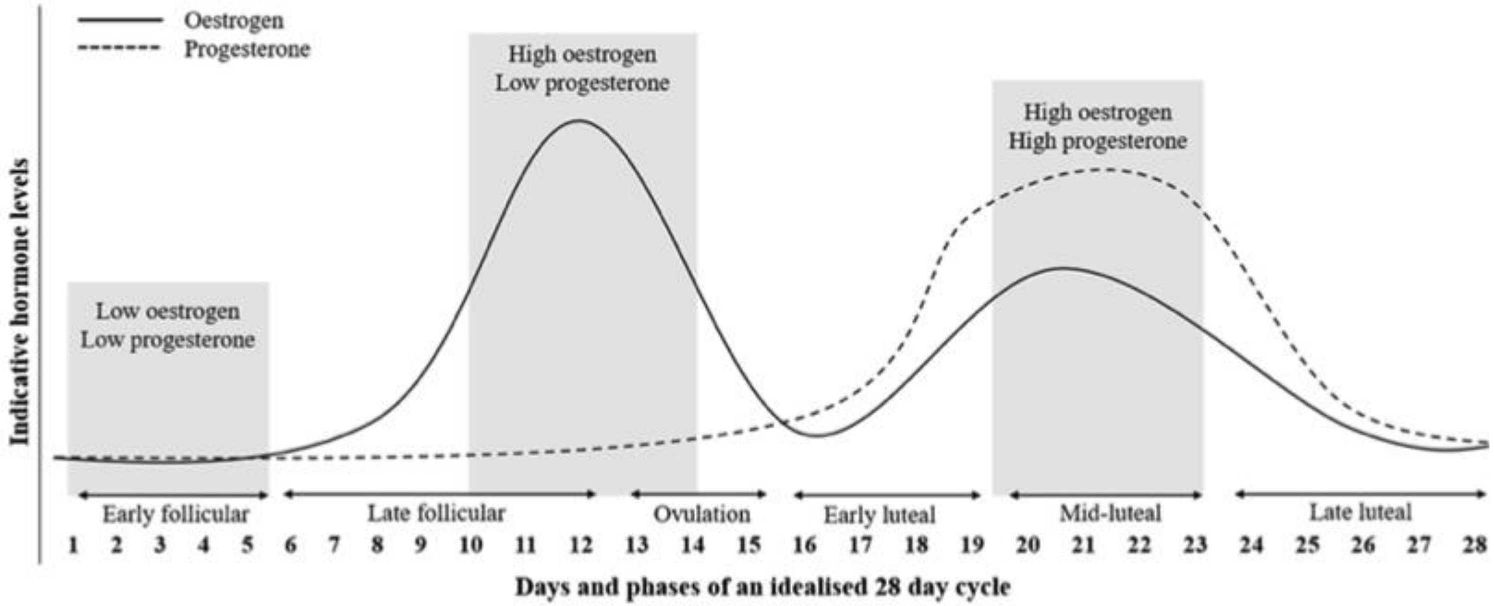


Figure 2-1 Idealised 28-Day Menstrual Cycle

*Schematic displaying the hormonal fluctuations across an idealised 28-day menstrual cycle, with ovulation occurring on day 14. Adapted from* Elliott-Sale & Pitchers, 2019.

## Section 2.1: Eumenorrheic MC characteristics

Menarche (the first menstrual period) typically starts during early puberty, around 11-13 years of age, and continues until menopause, which is the end of the MC process in the body, often occurring around age 50 [45,48]. The MC is usually referenced by counting days, starting with the onset of bleeding as day 1. The eumenorrheic or natural MC can vary in total length from cycle-to-cycle and person-to-person. The general consensus is that regular cycle length is between 22-35 days in total [33,44,49], with ovulation occurring close to the middle of the cycle. These lengths differ slightly from the common understanding that an average cycle lasts 28 days, with ovulation occurring precisely at the midpoint on day 14 [49].

The average menstrual period bleed length (the time the menstrual lining is actively being sloughed) is most commonly between 3-5 days in a regular cycle [49]. Other characteristics of a regular cycle also vary in length, as the follicular phase can range from 10-18 days, and the luteal phase can range from about 12-14 days. Typically, there is more variation in the follicular phase length than the luteal phase [49,50]. The amount of variation in cycle characteristics varies between individuals but can also change in length from one cycle to the next in a given individual. Although it is not well-established what exactly causes this variation, several factors, including age, nutritional status, and body mass index, correlate with differences in cycle length [50,51]. Other lifestyle factors, such as stress and energy availability, may also correlate with cycle length fluctuation, but this area needs further research.

The MC hormones throughout each cycle are released into the bloodstream and have a primary effect on reproductive organs, but they also have secondary functions and impact other tissues in the body [5,10]. Oestrogen, for instance, has receptors in the musculoskeletal system, nervous system, and brain [18,35]. The wide-ranging effects of the fluctuating levels of MC hormones on other areas of the body, and their potential consequences for athletic performance, warrant further research.

## Section 2.2: MC irregularities

The process outlined above captures the progression of the eumenorrheic cycle. Many individuals do not always experience regular eumenorrheic cycles for various reasons, and there are a wide variety of irregular cycles found in the general population. Although there are conflicting results among studies on MCs in athletes, competitive athletes may be more likely to experience cycle irregularities than the general population [52]. In addition, clinically diagnosable conditions such as endometriosis, PCOS, primary and secondary amenorrhea, and oligomenorrhea can differentially impact physiology and are present among 5-35% of menstruating women depending on the age group, and population analysed [53].

In reproductive-age women, PCOS is the most common endocrine disorder and, therefore, the most frequent cause of cycle irregularities [43]. PCOS is a syndrome with three primary signs: the development of cysts (undeveloped follicles) in the ovaries, hyperandrogenism, and MC disturbances. However, a diagnosis does not require the presence of all three symptoms. Although many associate the condition with hyperandrogenism, not all cases show this characteristic, causing variation in the presentation of this syndrome [43]. There has yet to be definitive research demonstrating that PCOS is more frequently diagnosed among athletes than the general population.

However, due to its overall prevalence, it is important for athletes and coaches to be aware of signs and symptoms of PCOS.

Other MC irregularities include heavy menstrual bleeding, or menorrhagia, which can be accompanied by iron loss. In a survey of elite-level female athletes, 37% reported heavy menstrual bleeding [54]. Similarly, in a survey of Australian female athletes, 29.7% indicated they experienced heavy menstrual bleeding, and those athletes were also more likely to report increased levels of fatigue [12].

There are other MC irregularities that are not always detectable by the individual and are not frequently diagnosed without close monitoring, such as during fertility treatment or research, due to their subtle differences from regular cycles. Anovulatory cycles and luteal phase defect cycles are irregular cycles where part of the expected hormonal cycle fluctuation does not occur, causing a different hormonal profile, namely lower progesterone levels, than those seen in regular MCs [55]. It is unclear how common these subtle irregularities are in athletes. However, in a study where hormone levels were monitored in exercising women, it was reported that 25% of cycles were anovulatory and 27% of cycles monitored had luteal phase defects, indicating that a notable portion of cycles monitored did not meet the regular cycle hormonal profile criteria [19]. These results prompt caution when classifying the criteria for a “regular cycle” based solely on the cycle’s duration in days. The potentially high prevalence of irregular cycles in athletes has implications both for the researcher and coach since these subtle irregularities will not align with predicted rises in hormone levels and will have a unique hormonal profile with currently unknown effects on performance or training.

## Section 2.2: HC

Many women use HCs which alter the natural cycle by creating an exogenous hormonal profile. The prevalence of HC use in athletes ranges from 10-50%, depending on the source, sport, and country surveyed [11,12,56,57]. HC use is often higher in athletes than in the general population [58]. There are many different brands, doses, and types of HCs available worldwide. The most common HC used by athletes is the combination oral pill, which delivers both oestrogen and progestin in a daily dose [57,59,60]. Although different brands vary in pharmaceutical make up, the main aspect all HCs have in common is that exogenous hormones alter the endogenous hormonal fluctuations of the natural cycle, creating a markedly different hormonal profile.

Some athletes utilise HCs to manipulate the MC by taking the hormone pills continuously to avoid menstrual bleeding on specific days to avoid MC symptoms or potential performance decrements during competition [61]. HC cycle manipulation appears to be common among athletes [62], and in one survey, 74% of athletes who take HCs reported using HCs to manipulate their MC at some point for competitive advantage [60]. HC cycle manipulation is an interesting area for those considering the hormonal profiles of athletes, as this creates yet another subset of hormonal variance and potential MC-related effects and concerns.

## Section 2.3: MC Symptoms

One of the most relevant aspects of the MC for many athletes is MC-related symptoms. Many different symptoms are associated with the MC, with some of the most common and frequently referenced physical symptoms including lower abdominal cramps (dysmenorrhea), lower back pain, increased appetite or food cravings, breast pain or tenderness, abdominal bloating, fluid retention, headaches, nausea, dizziness and gastrointestinal disturbances (including changes to bowel movements) [11,12,63,64]. In a survey of naturally cycling Olympic-level athletes, 81% reported experiencing physical MC-based symptoms [40]. One of the most notable MC symptoms for many athletes is dysmenorrhea—pain that is typically felt in the lower abdomen, which originates from uterine prostaglandins during the process of endometrial sloughing [65]. In a survey of Australian athletes, those who experienced dysmenorrhea-related pain linked this symptom to increased fatigue and perceived reductions in performance [12]. Dysmenorrhea appears to be very prevalent in both the athletic and general populations, ranging from 71% to 91%, depending on the specific subset of women analysed [12,40,43].

PD is the term used for painful menstrual cramps and the associated symptoms when no other disease pathology is present [64,65]. Despite its extremely high prevalence and ability to interfere with daily life and athletic performance, PD is infrequently diagnosed and insufficiently treated; often, it is even normalised by patients and practitioners alike and dismissed as an inevitable part of the MC [6,65]. This normalisation of MC pain can be problematic since it may dissuade those with underlying conditions that present similarly to PD from seeking the care needed to receive a diagnosis. Endometriosis, which is a condition where tissue similar to the endometrium is found outside the uterus [66], was diagnosed in 70% of adolescents who were unresponsive to initial therapy for PD [65]. It is therefore important for athletes that experience severe MC pain to seek medical advice rather than ignoring their symptoms.

## Section 2.4: Psychological symptoms of the MC

Many individuals report experiencing psychological symptoms as part of their MC, including mood changes, irritability, lack of motivation, anxiety, and depression [11,12,67]. For most individuals, these psychological symptoms emerge during the premenstrual phase—the days just before the onset of the menstrual period and last through the first few days of the menstrual period [11,68]. Up to 90% of athletes report experiencing MC symptoms that include mood disturbances, many indicating these symptoms are severe enough to miss work or school; 80% report that these symptoms impact their training every MC [6,8,11]. The authors of a recent qualitative survey on elite-level athletes speculate that psychological symptoms can have a major impact on training and performance [40], and related quantitative research has supported this theory [67]. Therefore, psychological symptoms should not be dismissed as irrelevant; instead, this issue requires further research in order to find potential solutions. Specifically, more research is needed to determine the causes of psychological symptoms, their severity, as well as the inter- and intra-individual differences in how these MC symptoms manifest.

## Section 2.5: PMS

The term PMS refers to both psychological and physical symptoms that occur during the end of the luteal phase until the first few days of the menstrual bleed 52. The American College of Obstetricians and Gynaecologists recommend that one of six psychological criteria (depression, angry outbursts, irritability, anxiety, confusion, social withdrawal) and one of four physical symptoms (breast tenderness, abdominal bloating, headache, swelling of extremities) be observable for five days before the menstrual period begins and subside within four days of the onset of menstrual bleeding to meet the criteria for PMS [52,69].

The exact cause of PMS symptoms is poorly understood, but emerging theories focus on the constantly changing levels of hormones in the body in conjunction with the changing ratios of key hormones (i.e., the ratio of progesterone to oestrogen levels) and how the body responds to these differing hormone levels [11,70]. The pathophysiology of PMS may also be attributed to the effects of progesterone levels on certain neurotransmitters, including serotonin, opioids, catecholamine, and gamma-aminobutyric acid [63,68]. Another theory on PMS aetiology examines the connection between inflammatory responses and PMS symptoms [70,71]. Currently, limited preliminary evidence demonstrates that women who experience PMS may also experience higher levels of inflammation than those that do not experience symptoms, and the overly robust inflammatory response may be the cause of some PMS symptoms [72]. This theory gives rise to the concept of nutritional intervention, micronutrient supplementation, and other anti-inflammatory measures as a method of counteracting PMS symptoms, though further research is needed to identify specific treatments that are effective in targeting these biological processes.

## Section 3: MC effects on performance

When considering the effects of the MC on athletic performance, the primary consideration is the degree to which hormonal fluctuations may affect various processes within the body that are responsible for both physical adaptations to training as well as the execution of performance-based tasks. One method some researchers use to examine the effects of MC hormones on performance and training, is to look at the specific differences during distinctive phases of the MC, thereby observing the effects of the associated hormones. If resistance training adaptations and strength outcomes are consistently affected by MC hormonal phases, there may be a preferable time within the natural MC to train or compete, or a preferable training structure specific to the MC.

## Section 3.1: MC effects on strength and power outcomes

Researchers looking at MC effects on strength and power-based performance have primarily focused on using varying strength and power-based tests during different phases of the MC and then implementing a cross-over study design to compare participant outcomes. The comparison of a participant's strength from one MC phase to the next may show the effects of the MC hormones that are dominant during each phase. Specifically, MC effects on strength, power, and muscle fatigability will be reviewed as these parameters are important for performance for RT athletes.

When comparing strength outcomes across the MC, it is unclear if there are distinct differences between phases [17,73]. In a systematic review and meta-analysis 16 seven studies that implemented a measurement of isokinetic peak torque of the knee extensors were analysed with no significant effect of MC phase reported. It was also noted that 11 studies that reported a measurement of maximal voluntary contraction were analysed, and no significant effect of MC phase on strength-based results was found. Another systematic review [73] analysed four studies that reported a strength-based assessment and found the results of the studies to be equivocal in regard to any MC phase-specific effect, with inconsistencies depending on the MC phase and the specific task implemented. In a final systematic literature review, McNulty et al. (2020) found that there was a slight decrease in strength performance during the beginning of the follicular phase. However, the authors also noted that this decrease in performance was trivial in nature and may not have practical application. The current consensus among researchers in this area is that the effects of the MC on measures of strength performance are potentially minimal on average and at worst, unclear at this time 4.

The MC appears to have little effect on other measures of athletic performance, such as power and muscle fatigability. Blagrove and colleagues (2020) analysed 10 studies that used an explosive strength-based measurement (such as vertical or horizontal jump height) and found a trivial difference in outcomes with no clear difference in regard to a specific MC phase. The effects of the MC on muscle fatigability, an exercise-based reduction in force production [74], was analysed in a review by Pereira et al., (2020); the authors reported it was not strongly influenced by MC phase. These reviews indicate that the major performance parameters for RT athletes seem to be minimally or not at all affected by MC phase across the broader population [4].

This raises a question: although many athletes report feeling that their performance is affected by their MC [11,46], why are there no clear objective measurements that confirm this lived experience? There are various theories for why the research is currently incongruent with athletes' reported experiences. One theory for this research discrepancy — and an important point to consider for both researchers and coaches — is the inter- and intra-individual variations in MC symptoms and hormone levels [16,75]. Since there is a broad range of normal MC hormone levels from person-to-person, which also varies from cycle-to-cycle for one individual, group-based findings in research studies may wash out this variation, despite it impacting individual results [75]. Another theory for MC research incongruency, and a major factor to consider when looking at existing research in this area, is that there are inconsistencies in methodology used to compare MC effects, such as the method used to determine cycle phase (calendar counting compared to direct hormone markers such as blood draws), phase time points (which day of the cycle is used to classify a given phase), and the number of time points measured (e.g., two time points per cycle versus six time points per cycle) [4,13]. These differences in study methodology further complicate the comparison of MC study results. Meignié et al. (2021) concluded that the connection between athletic performance and MC effects is difficult to identify within the current body of research due to the aforementioned aspects, as well as potential confounding variables, such as training load, injuries, nutritional strategies, and stress states. This lack of consistent methodology combined with a large number of low-quality studies in this field makes drawing conclusions about the effects of MC hormones on athletic performance problematic at this time [4,13].

## Section 3.2: MC effects on resistance training and MC phase-based training programmes

MC phase-based training is a concept that aims to guide the scheduling and progression of resistance training programming according to the natural cycling of hormones [15]. The studies in this area have focused on changing the frequency and intensity of training depending on the phase of the participant's MC with the aim to increase training demands during specific hormonal environments [39]. The most frequently used research design divides the eumenorrheic MC into the follicular and luteal phase. Participants increase training frequency for one half of the cycle and decrease training frequency for the other half of the cycle. Then, using a cross-over design, the opposite schedule during the next MC for the same participant is implemented, with a comparison of strength and hypertrophic outcomes between the different training schedules [15,39]. Reis et al. (1995) reported that when participants followed the high frequency follicular phase-based training schedule—performing unilateral leg resistance training three times per week at the first half of the cycle and then only once per week in the second half—they achieved significantly greater improvements in maximal isometric quadriceps strength (32% improvement) compared to participants who followed a training schedule that was not aligned with the individual participant's MC and performed training two times per week throughout the whole MC over eight weeks (13% improvement). A similar study by Sung et al. (2014) reported comparable results, showing that higher frequency unilateral leg training during the follicular phase resulted in greater increases in quadriceps muscle diameter (9%) compared to when participants completed more frequent training during the luteal phase (6%).

The potential increase in strength outcomes and hypertrophy from higher frequency training during the follicular phase supports a theory that a higher ratio of oestrogen to progesterone—as is the case during the follicular phase—may be favourable for strength and hypertrophy gains from resistance training [39]. In contrast, another study that examined MC phase-based training schedules found no significant difference in any strength or hypertrophy outcomes when training frequency was increased in the follicular phase, although this study differed from the previous two as it consisted exclusively of unilateral upper limb resistance training [76]. These conflicting results and the relatively small amount of data on the effects of altering training frequency based on MC phase demonstrate that this area needs further development to better elucidate MC phase-based training results and benefits.

## Section 3.3: HCs and performance

HCs create an exogenous hormonal profile different from the natural cycle, which raises the question of whether this altered hormonal profile influences performance outcomes. People taking HCs typically take the pills in cycles of three weeks of pill use followed by one week of sugar pill use [42,59]. Since there is one week without pill use each cycle, some researchers have used this pill-free week as a time to compare performance against the HC consumption weeks to measure the effects of HCs on performance. In a study by Reif and colleagues (2021), no significant difference in knee flexor and extensor strength was observed between HC use and abstention. This lack of significant difference in strength performance aligns with the current widely held stance that HC phase does not have a clear effect on performance [42] .

When comparing the effect of HC use versus the effect of the natural MC on strength performance, it is also difficult to draw strong conclusions based on current evidence. A recent systematic review with meta-analysis by Elliott-Sale et al., (2020) showed that HC use may lead to a slight decrease in strength performance compared to the natural MC. As the authors noted though, this may vary considerably from person-to-person depending on the reason that an individual is taking the HC (e.g., if an athlete is taking HCs for severe symptom mitigation, there may be a beneficial effect of the HC, as opposed to those who experience adverse side effects from HCs), the type of HC formulation, and the sport or type of performance being measured, as all of these factors may lead to different outcomes and would need to be isolated to further draw conclusions in this area [42]. Subsequently, Myllyaho et al., (2021) found no significant difference in strength or body composition outcomes between HC users and non-users in a population of physically active women. Other studies have shown a difference between HC users and non-users in resistance training adaptations. Oxfeldt et al. (2020)

found that after a ten-week resistance training programme, muscle fibre cross-sectional area of type II fibres tended to increase in HC users compared to non-users. Further, the authors specified that these results may be related to the untrained study population and noted that only the 2nd generation HC-users experienced this outcome [78]. These studies serve as a small sample to illustrate the wide range of findings related to HC use and muscle development. Due to the complexity of related HC-based results, further research that isolates the HC type and targets specific levels of athletic experience is needed to better elucidate HC effects on performance.

## Section 3.4: Psychological considerations and performance

Multiple studies, surveys, and systematic reviews have reported that females perceive their performance is affected by their MC phase [46,54,79]. In a literature review by Paludo and colleagues (2022), the authors reported that in two studies, female athletes reported that positive perceptual measures, such as motivation and feelings of competitiveness, increased during the ovulatory phase. This aligns with the aforementioned concept of the oestrogen dominant, mid-late follicular phase being favourable for athletic performance and training. It was also reported that negative perceptual responses were exacerbated in the late luteal and early follicular phase compared to other parts of the MC 80. These perceptual responses to the MC during the late luteal and early follicular phases may be the cause for reported discrepancies in perceived changes in performance compared to objective performance measures.

When considering effects of the MC on elite levels of athletic performance, an important factor is an athlete's mental readiness to perform. One aspect to consider is the timing of a competition within an athlete's MC. In a survey by McNamara et. al

(2022), two-thirds of Olympic-level naturally cycling athletes reported that when given the choice they would prefer to compete during their mid-follicular phase. This high level of consensus gives rise to the concept that there may be phases of the MC that are psychologically preferable for competing, even without definitive objective data showing a performance effect [40].

There are a few important points to note regarding research on preferable competition timing. One is that even with limited direct data in this area, the mid-follicular phase with its high level of oestrogen is postulated as the physiologically favourable phase for strength performance [37]. The preferred window for performance during the follicular phase could be due to the anabolic and neurological excitability properties of oestrogen causing a more favourable hormonal profile for both recovery and performance [37]. Improved feelings of recovery may cause an increased feeling of mental preparedness for subsequent training. The second important aspect of athletic performance to consider is the way in which preconceptions may influence performance success. If athletes believe that a specific phase will help them feel their best to compete, this may have an actual impact on performance separate from any direct physiological effect that hormones may have. Further studies that look at both the effects of mental expectation as well as hormonal effects on muscle or nervous tissue are warranted to better understand the reason why athletes prefer to compete in a specific MC phase.

## Section 4: Low energy availability and body image

Female athletes have a unique relationship with their bodies, and the term “female athlete paradox” is used by Voelker and colleagues (2020) to capture a commonly seen dichotomy in female sports. The female athlete paradox describes the conflicting desire athletes may feel to simultaneously meet the aesthetic norms of hegemonic femininity while also maintaining a physique developed for athletic success. Since a normatively feminine appearance is often at odds with the pronounced musculature of a highly athletic body, female athletes may develop a problematic self-image and relationship with their body [81]. Athletes in strength and power sports typically develop a more muscular appearance than the idealised female body type portrayed in mainstream media, which is both advantageous and an inevitable side effect of high-level resistance training. Many female athletes report feeling pressure to appear more feminine, smaller, or petite in non-sporting social settings (which is the opposite of the pressure they may feel in competitive settings), and this contradiction can be a source of psychological distress [82]. More research is needed to understand how common BID is among RT athletes.

BID, such as the female athlete paradox, can lead to problematic and disordered eating patterns in an attempt to stay thinner or leaner, or to retain a smaller, more stereotypically feminine appearance [83,84]. Strength athletes experience an added factor and heightened risk for disordered eating due to pressures to achieve sport-specified weight classes, which can encourage extreme methods to achieve rapid weight loss, such as substantial and abrupt caloric restriction [85]. In a study that analysed MCs among athletes of varying sport types, it was reported that those in aesthetic-based and weight class-based sports were more likely to experience MC disturbances and irregularities—a common outcome of disordered eating—than general population-matched controls [58].

Disordered eating patterns can lead to RED-S, which is caused by insufficient calorie intake relative to one's lean mass after accounting for exercise energy expenditure, known as low energy availability [36,85,86]. RED-S includes many physiological consequences, including MC irregularities, negative impacts on muscular strength and performance, and more severe health consequences, such as bone mineral density deficiencies, impaired metabolic rate, and suppressed immune function [86]. The regularity of the MC can be viewed as a vital sign of metabolic and physical health. Therefore, a sudden onset of MC irregularity in an athlete could be a warning sign of potential low energy availability and potential risk for developing RED-S, which should prompt monitoring by a medical care team.

## Section 5: Possible solutions to MC symptoms, performance effects, and cycle regularity

The primary concerns of athletes and clinicians are the potential for MC symptoms to interfere with training and competition, and cycle irregularities that might not only affect performance, but which may also be connected to broader health concerns such as RED-S. As recognition of MC symptoms and the potential effects on performance gains traction, the logical progression of research within this field is toward symptom mitigation.

In a survey of 2020 Olympic athletes in Australia, close to half (46%) of the athletes surveyed reported using analgesics for MC-based symptoms [40]. Analgesic over-the-counter medications may be a useful treatment for pain-based symptoms, such as dysmenorrhea, low back pain, or headaches, but there are drawbacks to this solution. As with many medications, there are concerns about effectiveness, long-term use, and the risk of side effects [10,87], especially in combination with other medications or medical conditions. The primary drawback with analgesic use in athletes for MC symptoms is that this treatment may only provide relief for some but not all common symptoms. Specifically, physical symptoms like bloating, fatigue and psychological-based MC symptoms may not be fully resolved with analgesic medication, so further solutions are needed to support the female athletes who experience these symptoms.

Another popular solution for MC symptoms is HCs to regulate the rise and fall of endogenous hormones throughout the cycle. Many clinicians are likely to prescribe oral HCs to those with severe MC symptoms and irregularities to prevent bone loss and regulate the cycle [58]. HCs may not be an ideal solution for all, as many athletes experience notable side effects from HC use. Further HCs, rather than regulating the cycle, may simply mask cycle irregularities [57,88], which means HCs may work for some individuals but are not the ideal solution for all. There is also insufficient data to support the use of HCs for mitigating bone loss [89], which is further confirmation that HCs are insufficient for addressing all MC-based concerns. However, there is promising emerging research on the use of supplements and nutritional interventions for MC symptoms [71], but this field requires further development, especially in the context of athletic performance.

## Section 5.1: The feasibility of mind-body interventions for MC symptoms

When reviewing the most common and frequently experienced MC symptoms, psychological symptoms were among the highest reported by exercising females [11]. Moreover, physical symptoms, such as the pain associated with PD, may be exacerbated when psychological stress is high [90]. The correlation between physical and psychological symptoms leads to the hypothesis that targeting physical MC symptoms with a psychologically-based method may be an effective treatment and symptom mitigation option for a host of MC-based athletic concerns.

Psychologically-based interventions may also help address body-image dissatisfaction and potentially corollary MC irregularities. Body image concerns can lead to psychological distress, but can also be connected to other physical ailments, such as pain perception [91]. Therefore, body image concerns may contribute to MC symptoms and irregularities, and may also increase the probability of disordered eating and subsequent low energy availability. Programmes that use psychological and mindfulness-based methods have shown success in helping female athletes alleviate body image dissatisfaction, especially the desire to appear thinner [92] Therefore, further research on psychological methods of mitigating MC symptoms in athletes is warranted.

Yoga is an example of a mind-body practice that may prove useful for addressing both MC-related and body image-related psychological distress among athletes [25,93] Yoga can be practised as a form of mindfulness meditation and relaxation by connecting the mind to the body through movement and breath, allowing both the mind and body to relax [94]. Yoga has gained traction in the medical setting for the treatment of a variety of conditions due its ability to create both structural and functional changes in the brain [65,93]. In a 2019 study, Vaghela and colleagues found that a yoga intervention for MC symptoms had significant effects on symptom relief; specifically, an average of a 44-point reduction on the Premenstrual Syndrome Scale (a scale of PMS symptoms with a 220 possible point outcome) was observed among the participants who were referred by a practitioner for PMS. The reduction in symptoms from yoga may potentially stem from balancing the neuro-endocrinal axis and by downregulating hypothalamic pituitary adrenal axis action [94], both reducing stress hormone production and regulating the MC. In both individual studies and recent systematic reviews, authors report that yoga is an effective treatment for physical and psychological MC symptoms, pain mitigation, and

MC irregularities [23–25,93–95]. The significant effects of yoga support the theory that a treatment plan focused on the psychological well-being of the athlete via stress reduction, mindfulness, or body image dissatisfaction awareness may help resolve some MC-based concerns among female athletes. Future research on the use of yoga and mindfulness type programmes to improve women's athletic experiences is warranted.

## Section 6: Conclusion

In summary, the MC is a series of hormone actions within the body and is a vital sign of physical health in reproductive-age females. The MC can result in a range of physiological and psychological side effects that may affect athletic performance. Most women who experience MCs, including athletes, experience one or more MC symptoms every cycle. Currently, there is little consensus surrounding the effects of MCs on athletic training or performance. Due to the complexities in accurate hormone monitoring, the commonality of irregular MCs, and the variety of symptoms experienced, this under-researched area would greatly benefit from further high-quality studies. New and effective methods for MC symptom mitigation are necessary, and a mind-body based intervention, such as a mindfulness practice like yoga, warrants further investigation for symptom mitigation in athletic populations.

# Chapter 3 Menstrual cycle characteristics, hormonal contraceptive use, and perceptions of related effects in resistance-trained athletes

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### Prelude

The review of the literature (Chapter 2) revealed how little is known about normative MC characteristics and perceptions, especially in RT women. It also outlined how MC characteristics may vary among different population groups. Therefore, the first priority for this thesis was to establish MC characteristics, including HC use, among RT females and collect data on the perceptions of MC symptoms and their effects on performance and well-being. This chapter utilised a cross-sectional survey to capture this data.

## Section 1: Introduction

The hormonal fluctuations of the menstrual cycle (MC) cause a myriad of processes in the body linked to reproduction. In recent years there has been an increased interest in the effects the MC may have on sports performance [1–4]. A "normal" MC is approximately 22-35 days duration between menstrual periods in reproductive-age women [5]. A regular MC leads to a recurrent and cyclical process of rises and falls in estrogen and progesterone, and it is estimated that an individual will experience 451 MCs in their lifetime, starting from approximately age 12 to age 50 on average [6]. The MC can be considered a vital sign [7] and should be considered a crucial indicator of metabolic and physical health [7,8]. As a part of their regular MC, many females experience a wide range of symptoms related to hormonal fluctuations and menstrual bleeding, including physical pain and mood disturbances. Over 90% of young women, girls and those who menstruate in Australia [9], and almost three quarters of young women worldwide [10] experience period pain (dysmenorrhea). Very little evidence suggests that MC symptoms reduce significantly with age [11], hence most women will likely experience regular period pain at some stage in their life. In addition, it is perhaps unsurprising that menstrual symptoms such as period pain, and others such as heavy menstrual bleeding, reduced participation in sport [10,12] in both the general population and athletes alike.

Previous research has found that 83-93% of female athletes experienced MC related symptoms such as pain or heavy bleeding that may reduce training adherence or performance [13–15]. There is evidence that exercising females may experience different length cycles or cycle irregularities and amenorrhea at higher rates than their sedentary counterparts [16]. The prevalence of irregularities in different populations of exercising females is important for establishing MC characteristics and for establishing MC effects on performance but at this point is not well documented in the literature. The dearth of information on regular MCs in female athletes may lead to poorly informed training recommendations which may be detrimental for female athletic advancement. Previous research has found that 50% of athletes perceived their MC had a negative impact on performance [13]. Therefore, further understanding all components of the MC, including the perception of its effects on exercise, is an essential component to account for MC effects as a whole.

Hormonal contraceptive (HC) use is another important topic that impact the MC and potentially sports performance [17]. HCs create a unique hormonal environment that differs from the natural MC by using exogenous hormones to modulate the hormonal rises and falls normally seen in a natural MC [18]. Previous studies report that approximately 29.0-49.5% of exercising females worldwide use some form of HC for various reasons [13,14,19,20], but it’s unclear if there are any sport discipline or specific factors that influence HC usage. As part of developing a complete understanding of the MC, it is imperative to establish the prevalence and role of HC use in different sport populations to understand the effects they may have on training and performance.

Previous surveys focused on MC-related symptoms and characteristics of team sport or endurance athletes, women performing mixed exercise types (resistance and cardiovascular), or a mixture of female athletes and exercisers [13–15,19]. While previous information on MCs in athletes has been beneficial, there is a lack of differentiation of exercise and activity types in previous work. Resistance training is an important aspect of general exercise and is the primary training mode for strength sports. Strength-based sports include Olympic weightlifting, powerlifting, CrossFit, physique-based sports, throwing sports, and other related strength-oriented competitions. Since resistance training and strength-based sports are based upon different training styles than endurance training the impact of any MC changes may be different in these sport types, as different areas of the body and training styles are used. For example, a reduction in explosive power due to MC changes may be more detrimental in throwing sports than in marathon running.

Currently, there is a lack of data on the MCs of resistance-trained athletes. Normative data on MC characteristics, including the prevalence of irregularities and HC use, in the resistance-trained population will better inform the effects of the MC on strength performance. Understanding athlete perceptions about MC effects is a substantial component in establishing any actual MC performance effects, but there is a lack of data in this area, specifically in the resistance-trained population. There has been an increase in popularity on the topic of adjusting resistance training programming around the MC [21] , but further normative data on the MC in the target population is necessary to better inform these theories and practices. Therefore, the purpose of this survey was to determine the average MC characteristics, HC use, and perceived effects of the MC on training in resistance-trained athletes, and to determine if there are differences in these variables when comparing recreationally trained athletes to competitive-level athletes.

## Section 2: Methods

A survey was employed to explore MC characteristics and perception of the MC's effect on performance for resistance-trained athletes. Pilot testing undertaken with 10 athletes prior to survey launch included the understandability and appropriateness of the questions. Changes were made to the survey after this feedback and prior to the official launch of the survey. The final version of the survey was hosted on the Qualtrics Platform (Qualtrics Ltd., Provo, Utah, USA, March 2021). The cross-sectional online survey was anonymous, and participants were recruited via a social media recruitment poster. After participants viewed the recruitment poster on social media they could choose to follow a link to the survey, which began with an information page with the purpose and objectives of the survey as well as an explanation of any potential risks and benefits from participation. Participants were informed that they were giving their consent to participate by moving forward with the online questions. Interested participants could then click a "continue" button which demonstrated their consent to participate in the anonymous survey if they chose to do so. The survey took most participants between 10-20 minutes to complete and was made available from April 2021 until June 2021. This research was approved by Auckland University of Technology Ethics Committee on 5 March 2021 (AUTEC reference number 21/22).

## Section 3: Procedures

Participants completed the anonymous survey comprised of 79 questions. The survey had five sections: Participant Demographic/Background Information, MC Characteristics, HC Use and Characteristics, and Perceptions of MC effects. Demographic and background information included questions on age, experience with resistance training, including competitive level (if applicable), other types of training they participated in, and their geographic location. The MC characteristics section included questions about period regularity and MC symptoms, timing, and severity. The HC section included questions on the type of HC used, the main purpose for their use, duration of use, and any experienced side effects. The perception of MC effects section included questions about perceived positive or negative effects on performance, their timing, and severity. In the section on MC effects, participants were specifically asked if they felt their workouts were affected by their MC, giving the participant the choice to identify any part of their MC, such as the menstrual period or pre-menstrual time frame.

## Section 3.1: Participants

Participant inclusion criteria were females aged 18-50 who self-identified as not having experienced menopause. Participants self-identified as currently participating in a high level of resistance training and primarily participating in resistance-training exercise over any other exercise types. They participated in full-body resistance training and trained at least two times per week, and had at least a two-year training history. A current and regular MC was not an inclusion criterion as it was considered important to establish an accurate depiction of the frequency of amenorrhea in the target population. Participants who considered themselves to be competitive-level athletes were asked to self-identify as such, the criteria being that they actively competed in a strength-based sport, including Olympic weightlifting, powerlifting, CrossFit, or a physique-based sport regardless of their level or experience. These participants were considered 'competitive-level athletes' to differentiate them from recreational-level athletes for analysis. Based on the criteria outlined by McKay and colleagues on defining training calibre [97], the competitive-level athletes in this survey would be classified as Tier 3 and above, and the recreational-level athletes would be classified as Tier 2.

## Section 3.2: Statistical analyses

Descriptive data, including means, frequencies, standard deviations (SD), modes, percentages, and ranges were reported for each section to establish normative data in this population. Chi-square tests were used for group comparisons, specifically for analysing differences in competitive-level athletes compared to recreational-level athletes for MC characteristics, HC use, and MC perceptions for categorical data as well as for group comparisons between HC users and nonusers. Strength athletes were defined as any participant who indicated they were competitive in a strength sport, regardless of competitive level. Effect sizes were calculated with Cramer's V. Effect sizes were reported with degree of freedom of 1 ≥0.1 represents a small effect, ≥0.3 represents a medium effect and ≥0.5 represents a large effect, degree of freedom of 2 ≥0.07 represents a small effect, ≥0.21 represents a medium effect and ≥0.35 represents a large effect, degree of freedom of 3 ≥0.06 represents a small effect, ≥0.17 represents a medium effect and ≥0.29 represents a large effect [98]. Incomplete or missing data (unless the missing data was in the optional nutrition section) were excluded from final analyses. Significance was determined at the $p \leq 0.05$ level. All statistical analysis for this research was performed using JASP Team (Amsterdam, The Netherlands, 2023). JASP (Version 0.17) (https://jasp-stats.org/) computer software for Mac.

# Section 4: Results

## Section 4.1: Demographic and background characteristics

Demographic and Background Characteristics:

Nine hundred and six participants accessed the survey online. Participants who did not meet the survey criteria were removed, leaving 809 responses that were analysed. Participants ranged in age from 18 to 48 years, with a mean age of 27 ± 5.95 years and most commonly had been doing resistance training for 6-10 years (30.5%). Hours of weekly participation in resistance training ranged from 1-2 hours per week (2.7%) to 7 or more hours per week (31.1%), with most participants training 5-6 hours weekly (44.5%). A total of 267 participants (33%) self-identified as competitive-level athletes with most of these athletes competing at the regional or national level (88.3%). Further information on competitive athletes is shown in **Table 3-1**. Participants from 53 countries completed the survey with the following breakdown: a majority (57.5%) from the USA, followed by New Zealand (7.7%), the UK (7.1%), Canada (7.0%), Australia (5.4%), Europe (7.0%) Asia (2%), the Middle East (2.0%), Latin America (1.0%), and Africa (0.5%).

Table 3-1 Strength athlete characteristics

| What sport do you currently compete in? | Percent | Count |
|---|---|---|
| Weightlifting | 11.1% | 32 |
| Powerlifting | 51.7% | 149 |
| Strongman/Strongwoman | 2.1% | 6 |
| Physique based sport (bodybuilding of any type) | 11.1% | 32 |
| Throwing based sport (shotput, discus, javelin etc.) | 0.7% | 2 |
| CrossFit | 10.1% | 29 |
| Other | 12.9% | 37 |
| **What is the highest level you have competed in your sport?** | | |
| Regionally/Locally | 48.8% | 141 |
| State or National Level | 36.7% | 106 |
| International or elite level | 10.4% | 30 |
| Other | 4.2% | 12 |
| **How many years have you competed in this sport?** | | |
| 1-2 years | 44.4% | 127 |
| 3 -4 years | 32.5% | 93 |
| 5-6 years | 9.8% | 28 |
| 7 or more years | 11.5% | 33 |

## Section 4.2: MC characteristics

The mean age of menarche reported in this population was 13 ± 1.7 years; the mode of reported menarche age was 12. Most participants (68.3%) answered that their periods came regularly, with (72.7%) reporting that their MC lasted 25-31 days. Strength athletes were comparable, with 68.1% indicating that their periods came regularly and 75.7% reporting that their MC lasted 25-31 days. There was no significant association between number of hours of training per week and MC regularity ($p = 0.69$). More detailed information on MC characteristics and irregularities is in **Table 2**. 11% of participants reported experiencing amenorrhea in the last two years due to factors connected to low energy availability (such as physique contest preparation, dieting, excessive training, etc.). There was no significant association between hours of training per week and experiencing amenorrhea ($p = 0.661$). 5.6% reported they were diagnosed by a healthcare provider with amenorrhea, and 9.3% of participants with a MC irregularity, with polycystic ovary syndrome (PCOS) being the most common irregularity diagnosis. Competitive-level athletes had a similar frequency of MC irregularities (8.8%). There was no significant association among competitive-level athletes and MC irregularity diagnosis ($p = 0.664$). 75.3% of participants tracked their MC using an app or calendar counting. 92% of participants stated they experience MC-based symptoms, with uterine cramps the most cited symptom (76%). HC use was associated with a lower likelihood of MC symptoms overall ($p < .001$) with a small effect (effect size = 0.167) and specifically a lower likelihood of cramps ($p < .001$) with a small effect (effect size = 0.147). Participants indicated their worst symptom severity was $5.47 \pm 1.9$, on a pain scale from 1-10. Most (76%) of participants indicated they did not experience iron anaemia. A complete breakdown of symptoms and related details is found in **Table 3-2**.

Table 3-2 Menstrual cycle characteristics

| MC Symptoms | Percentage | Count |
| --- | --- | --- |
| Menstrual cramps | 76.0% | 615 |
| Headaches | 43.1% | 349 |
| Breast pain | 45.2% | 366 |
| Bloating | 72.0% | 583 |
| Digestive distress | 51.7% | 419 |
| Fatigue | 62.0% | 502 |
| Changes in mood | 71.5% | 579 |
| Other | 7.4% | 60 |
| **Diagnosed MC Clinical Irregularities/Gynaecological Conditions (9.3% of all participants)** | | |
| PCOS | 60.2% | 50 |
| Amenorrhea | 6.0% | 5 |
| Menorrhagia | 6.0% | 5 |
| Endometriosis | 16.9% | 14 |
| Oligomenorrhea | 0.0% | 0 |
| Luteal Phase deficiency | 3.6% | 3 |
| Unsure | 3.6% | 3 |
| Other | 3.6% | 3 |
| **Experience Heavy Bleeding** | | |
| Yes | 18.2% | 140 |
| No | 66.6% | 512 |
| Unsure | 5.2% | 27 |

## Section 4.3: HC characteristics

40.2% of participants indicated they use HCs. The combined oral contraceptive pill was the most common (43.8%). A majority (67%) indicated they had used this HC method for over two years. Fewer competitive-level athletes used HC (38.4%). The most common reason for HC use was for contraceptive purposes (72.8%), and the second most common reason was for MC symptom relief (13.7%). 45.4% of participants believed their HC caused unwanted side effects. Figure 3-1 displays further HC information.

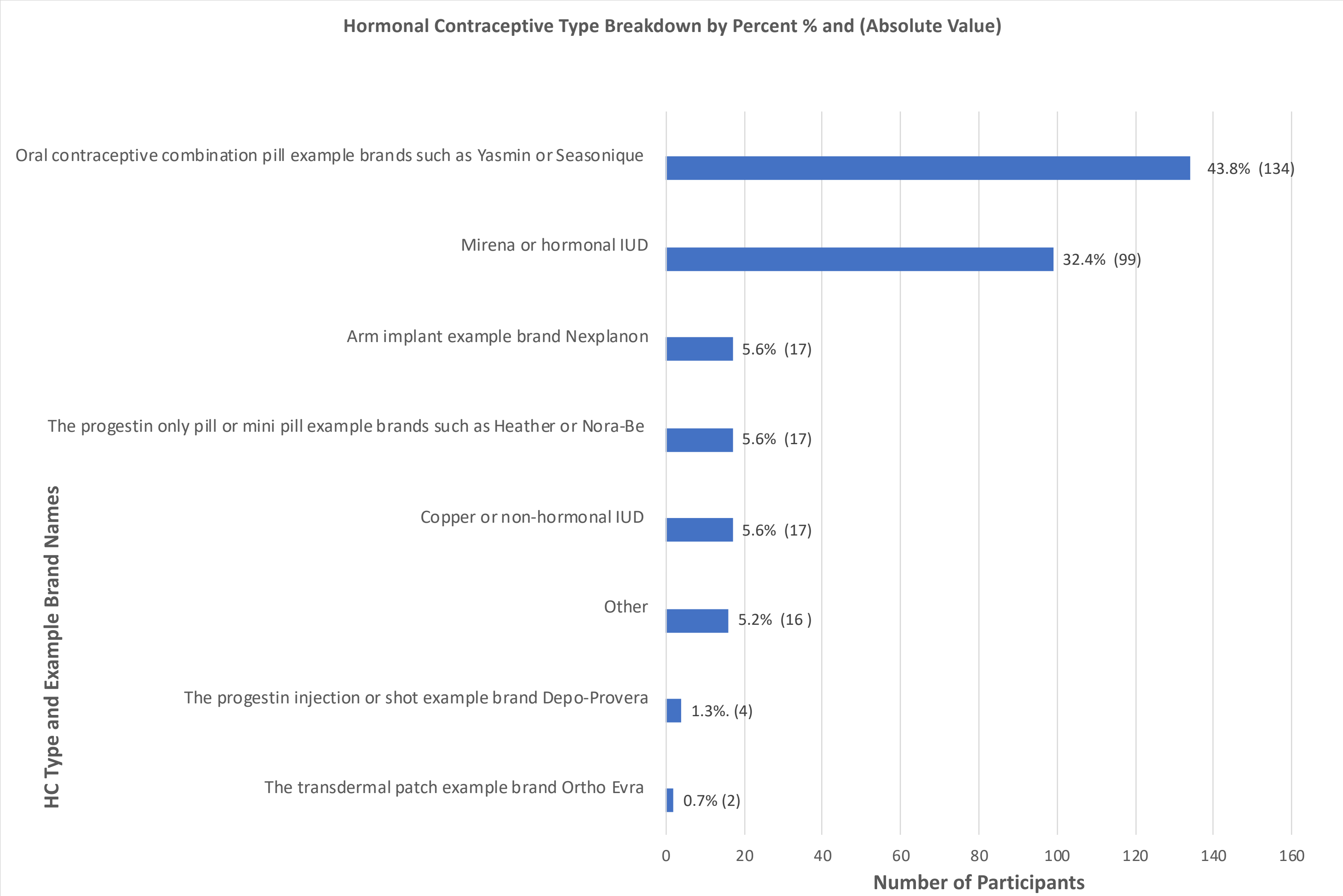


Figure 3-1 Distribution of HC type

59.4% of participants perceived their MC had a negative impact on training or performance, but 46% perceived their MC had a positive impact on performance. Most participants cited the negative impacts on performance occurring in the days leading up to menstruation or during menstruation (89.5%), and 38.0% perceived the positive effects to occur in the week after menstruation. The most reported negative effect was fatigue (43.4%), and the most reported positive effect was feeling stronger (34.8%).

Competitive-level athletes were comparable, as 64.9% perceived their MC had a negative impact on performance, and 38.0% perceived their MC had a positive impact on performance; there were no significant associations between competitive-level athletes versus recreational-level athletes and the perception of negative MC impacts on performance ($p = 0.080$) or positive impacts on performance ($p = 0.954$).

69.5% of participants altered their program due to MC symptoms, with decreasing load or volume as the most cited alteration (83.3%). Competitive-level athletes were significantly less likely to alter their training due to their MC ($p = 0.008$) with a small effect (effect size = 0.145) compared to recreational-level athletes. Only 1% of competitive athletes had ever dropped out of a competition due to MC-related concerns.

85.7% of participants felt comfortable discussing their MC with their coach. The most cited reason for not discussing their MC with their coach was that their coach was male (72.7%). Competitive-level athletes were slightly more likely (90.5%) to feel comfortable discussing their MC with their coach. See **Table 3-3** for all Chi-Square test results associated with this data set.

Table 3-3 Chi-Square test results

| Comparisons | X2 | df | p-value | Effect Size |
|---|---|---|---|---|
| Strength athletes versus non-athletes and MC irregularity diagnosis | 0.19 | 1 | 0.664 | 0.1 |
| HC use and MC symptom cramps | 17.9 | 1 | <0.001 | 0.2 |
| HC and MC symptoms general | 21.8 | 3 | <0.001 | 0.2 |
| Strength athletes and negative perception of MC | 5.0 | 2 | 0.080 | 0.1 |
| Strength athletes and positive perception of MC | 0.09 | 2 | 0.954 | 0.1 |
| Strength athletes and alter training | 7.1 | 1 | 0.008 | 0.2 |
| Hours per week resistance train and periods regular | 11.3 | 9 | 0.253 | 0.1 |
| Hours per week resistance train and amenorrhea | 1.6 | 3 | 0.661 | 0.1 |

## Section 5: Discussion

This survey focused on MC characteristics, HC use, and perception of MC effects on training and performance among females who participate in resistance training both competitively and non-competitively. Like the broader population, participants reported high rates of MC-related symptoms, and slightly less than half used a form of HC. However, contrary to existing research on other exercising women, most participants reported regular menstrual cycles. Further, most participants perceived that their MC had a negative effect on their performance. However, in those who were competitive-level athletes, a vast majority indicated that they had never dropped out of a competition due to MC symptoms. Besides this difference, competitive and recreational-level lifters in the present sample reported similar MC characteristics, symptoms, and symptom severity levels.

The findings from this study on MC regularity aligns with previous related research on MCs among the general female population [24] and contrasts research on females performing general exercise [16]. De Souza et al.,[16] used active hormonal monitoring to categorize MC regularity rather than memory recall (the method used in the present survey) which may explain the contrasting findings. Therefore, further investigation is warranted regarding the prevalence of MC irregularities and their effects on performance among resistance-trained women, specifically using hormonal monitoring techniques.

In line with previous surveys showing that a vast majority of exercising females experience MC symptoms [13,14] 92.0% of our respondents reported experiencing MC symptoms as well. Cramps were the most listed symptom (76.0%), and most reported symptoms occurred at the end of the luteal phase and/or the beginning of the menstrual period (91.6%). These findings align with research on other types of athletes as well, as the timing and type of observed MC symptoms were similar in studies on runners and swimmers [12,25]. The pain severity of symptoms in this current study was also notable, with most participants listing their worst symptom as a mean of 5.5 on a scale of 10, or “moderate” on the pain scale. Previous research has shown that this pain severity level may impact one’s physical capability for multiple days every month, causing them to miss important activities of daily living, including training [9]. Indeed, competitive-level athletes or their coaches may benefit from considering MC pain severity when programming training. Understanding the breadth and intensity of MC symptoms can improve the effectiveness of coaching for female athletes and the individual experiences of athletes by providing context and validation for real-life experiences.

The high prevalence of HC use found in this study aligns with some previous findings, with close to half of the participants utilizing some form of HC and a majority using combined oral contraceptive pills [13,20]. However, the present findings differ from a recent survey which found relatively low HC use (approximately 10%) in a women's football group surveyed in South Africa [26]. The authors attributed this lower level of HC use to cultural and socioeconomic differences in the region [26]. Other previous research has shown that HC use varies widely across countries and regions worldwide [27]. Notably, the present survey was primarily composed of participants from similar culturally Westernized countries (84.7% of respondents were from the US, UK, New Zealand, and Australia, combined). Therefore, when there is a difference in HC use prevalence between regions as possibly indicated by some data, researchers should be aware of these contextual differences when generalizing HC use among athletic populations globally.

Another important finding of this study is the high prevalence of side effects from HC use. 45.0% of participants in this survey indicated they experience some sort of HC side effect. Despite this large percentage of reported side effects from HC use, HC use was associated with a lower likelihood of experiencing MC symptoms overall, including cramps specifically. Similarly, in prior research, 40% of elite female athletes who used HCs also perceived that HCs caused adverse side effects [20]. Of note, many females are prescribed HCs to alleviate their MC symptoms [18,19]. While the present survey supports the notion that HCs may alleviate MC symptoms for some individuals HC use alone may not be a sufficient remedy for all who experience MC symptoms since a large number may still experience some level of unwanted side effects specifically from HC use. Ultimately, whether the trade-off of MC symptoms for HC-related side effects is worth it, resulting in a net improvement, warrants further investigation. Further research is also needed to discover new antidotes for MC symptoms that produce a lower rate of unwanted side effects.

Most participants perceived that their MC negatively impacted performance (59.4%), specifically during the late luteal phase or the onset of the menstrual period. This is slightly higher than previous related research on marathon runners, where 41.7% perceived that their performance was negatively impacted by their MC [12]. However, the present rates are similar to those reported (65.6%) in previous research on a mixed group of elite athletes [28].

In the present study, fatigue was the most commonly cited negative side effect (62%) that impacted training. This finding aligns with research on other athletic populations of females that found that fatigue was a common MC symptom impacting performance [12,19]. In the present study, a considerable number of participants indicated that they made alterations to their training due to their MC (69.5%), with reducing load or volume being the most common alteration. The prevalence of MC-based fatigue is important for the athlete and coach to be aware of. Like pain, fatigue may also need to be considered prospectively for workout programming, as fatigue may prompt training load and volume reductions.

Although more than half of competitive athletes perceived that their MC affected performance during competition, only 1% reported dropping out of a competition due to their MC. This is mirrored in a survey of competitive athletes, where most high-level athletes reported negative side effects related to their MC, but only

4.2% reported refraining from exercise during specific times of their MC [20]. This finding may demonstrate that although competitive athletes often experience the same level and intensity of symptoms as the general exercising population, their competitive drive may override the desire to refrain from exertion, especially for a one-time event like a competition. This finding aligns with previous research on athletes, which found many athletes are willing to push through pain due to passion for the sport, athletic identity, normalization of pain in sports, and external expectations to perform under all circumstances [29,30]. This interesting difference between exercising women and female athletes in the present survey warrants further research to explore the connection between perceived MC impacts on performance, and the actual measured performance effects of the MC itself.

Most participants felt comfortable discussing their MC with their coach, but 14.0% did not, primarily due to their coach being male. This finding is echoed by Martin et al.[31] and Findlay et al. [15], as both reported that most female athletes were comfortable speaking about their MC with their coach, but not all felt this way. Since MC symptoms are common, it is crucial that all athletes with MCs are comfortable enough to speak to their coach about their symptoms, regardless of their coach's gender or sex. To facilitate such critical communication, male coaches can take the initiative to educate themselves on the topic of the MC in sport to encourage an open dialogue and give the athlete space to express concerns they may have surrounding their MC and performance.

## Section 5.1: Limitations of this research

Since this was a cross-sectional survey based on memory recall of events, answers are subject to recall bias. Another limitation of this research is that participants self-identified their level of participation in resistance training, including their experience, competitive level, and history. Therefore, the findings may not be an accurate representation of differences between (and characteristics of) recreational and competitive-level athletes. Many participants also reported participating in other types of physical activity, including cardiovascular training and team sports, making these findings potentially more varied than might be reported by a group of exclusively resistance-trained athletes.

## Section 6: Conclusion

Females who participate in resistance training, competitive or not, experience MCs similar to data on other exercising females, and the general population. MC symptoms are widespread and, for some, can be quite severe and limiting. In this study, MC irregularities were not more common in females who participate in resistance training compared to data on other exercising females, and PCOS was the most cited irregularity. Competitive-level athletes were not more likely to experience MC irregularities than recreational-level athletes.  Nearly half of the participants reported using HCs, with the combined oral contraceptive pill the most used form. Most participants perceived that their MC had a negative effect on their performance and that their MC can cause reductions in training load or workout program adherence, although most competitive-level athletes did not withdraw from competitions due to MC symptoms. As research continues to uncover more details about the mechanisms behind these MC experiences, future investigations should focus on solutions. In the meantime, an understanding and individualized response to the fatigue, pain, and other difficult MC symptoms is likely the best approach.

# Chapter 4 The associations between calorie tracking, body image dissatisfaction, eating disorders, and menstrual cycle characteristics in resistance-trained athletes

*Journal of the International Society of Sports Nutrition (In review)*

## Prelude

Chapter 3 demonstrated that MC symptoms are widespread and, for some, can be severe and limiting. In addition, most RT females perceived that their MC has a negative impact on their training and performance. Therefore, the purpose of Chapter 4 was to further expand on the topic of MC effects and explore other connections relevant to strength-based sports, namely mental health concerns such as body image dissatisfaction and eating disorders in conjunction with diet habits. Given the known prevalence of body image concerns and disordered eating patterns in physique and weight-class-based strength athletes and their connection to low energy availability and the female athlete triad, additional cross-sectional survey questions were provided to RT females to further explore these topics, which are analysed and discussed in the following chapter.

## Section 1: Introduction

Symptoms related to the menstrual cycle (MC) can impact performance in athletes [11]; however, most research is not on resistance-trained (RT) athletes. RT athletes engage in training that targets muscular strength development, specifically for sports including Olympic weightlifting, powerlifting, Crossfit, throwing sports, and physique sports. RT athletes' training differs considerably from cardiovascular endurance-based training; therefore, this class of athletes warrants sequestered research to isolate the specific nuances related to RT sports, such as weight-class restriction impacts and sport-related recovery. Further, while body image dissatisfaction (BID) and eating disorders (EDs) are relatively common in all athletes (ranging from 11-67% of athletes sampled, depending on the sport and method of assessment) [103]. EDs are also prevalent in weight-class restricted sports (a common format in strength sports) and especially among physique athletes [104].The prevalence of EDs among female physique athletes is currently unclear, but a recent survey found that 37% of participants were at risk of developing an ED [105]. RT athletes in weight-class restricted sports manipulate their nutrition to reach aesthetic or body weight standards, and in that process, they may undergo prolonged periods of low energy availability[104]. Low energy availability, defined as consuming insufficient energy for one's lean mass and exercise activity, can lead to relative energy deficiency in sport (REDs), a syndrome which can impact MC symptoms (and many other aspects of physiology and psychology) [86]. Moreover, there has not been a prior investigation into the relationships between these RT athletes' nutritional habits, MC-related symptoms, BIDs, and EDs.

The MC plays a vital role in women's overall health and well-being, and affects sports training, participation, and performance [13,18,43]. For most, the MC causes various symptoms that affect athletic performance measures and training capacity [10,12,13,16]. MC symptoms that affect performance include more than physical symptoms; most female athletes also experience mental health symptoms and changes in their perception of performance, which likely impact their actual performance outcomes [11,30,40,79,106]

The Female Athlete Paradox is the balancing of societal expectations of hegemonic femininity and the muscular physique needed for sports success. This dichotomy can lead to BID [81,92,107]. BID in athletes may stem from the internal pressure that athletes put upon themselves to look a certain way for their sport [108] and from the external pressure coaches put upon athletes, especially if the nature of the sport itself involves aesthetic components or weight-class based categories [109,110]. Athletes in aesthetic- and weight-class sports are more likely to experience MC disturbances than population-matched controls [5858]. This is likely due to a high prevalence of BID in aesthetic-based, leanness-based, and weight-class based sports, which is extremely common for RT athletes [85,108,111]. Previous research has shown connections between BID and the natural phasic changes of the MC [112], further establishing the link between the MC and BID.

One can experience low energy availability from disordered eating patterns well before they are diagnosed with an ED, especially in exercising females [51,83,84,113,114]. EDs are seen in athletes of mixed ages, sport types, and competitive levels [111,115,116]. EDs combined with low energy availability can alter MC hormonal patterns [117,118], typically manifesting as MC irregularities or amenorrhea [86]. REDs can negatively impact muscular strength and performance and cause more severe health consequences, such as bone mineral density deficiency and suppressed immune function [86]. Nutrition interventions to alleviate REDs, especially in the presence of EDs, contain layers of complexity in how they are delivered. Many interventions presume that athletes track and monitor their nutrition. While nutrition tracking in populations without a predisposition or history of EDs or disordered eating may not risk their development [119], those with a current ED, or a history of EDs, may be negatively impacted by dietary tracking due to the ability to fixate on calorie tracking in an app environment that may appear rewarding, therefore reinforcing restrictive behaviours [120]. Establishing the normative data on dietary practices of RT athletes is necessary to understand if there are links between caloric restriction and dietary tracking leading to REDs in this population.

Most research to date in the area of EDs and REDs does not focus on females who participate in resistance training-based sports, and instead focuses on mixed sport disciplines, or endurance-based athletes [111,116,121–123]. Since resistance training is an important and unique type of exercise that challenges the body differently than cardio endurance exercise training, it is necessary to establish normative data specifically for RT athletes.

General BID and calorie restriction practices that include rapid and significant weight loss (like those commonly used in weight-class based resistance training sports) can produce negative mental health consequences in athletes, which can lead to EDs [85,123]. EDs can have serious physical health consequences that can lead to a variety of conditions, including REDs, hypothalamic dysfunction, and MC irregularity [39]. Therefore, more knowledge on calorie restriction practices and the connection between BID and EDs with the MC in the RT population is needed. This exploratory survey was implemented to answer the following research questions: What are the calorie tracking and calorie restricting habits of RT females? What is the association between self-reported BID and MC characteristics among RT females? What is the association between ED diagnosis and MC characteristics among RT females? Are there differences in calorie tracking habits, BID, EDs, and MC characteristics between competitive-level RT athletes and recreational-level RT athletes? As this was an exploratory analysis, we did not formulate any hypotheses.

## Section 2: Methods

An anonymous online survey was implemented to explore the dieting habits, MC characteristics, BID, and EDs in RT females. The survey was designed based on pilot consultations with the target population. The survey was hosted on the Qualtrics

Platform (Qualtrics Ltd., Provo, Utah, USA, March 2021). Participants were recruited via social media promotions on the authors' Instagram pages. The online recruitment poster contained a link that gave interested viewers more information on the data collection procedures. The survey began with an information page that explained the survey's purpose, objectives, potential risks, and benefits. Participants gave their consent to participate by clicking a "continue" button and commencing the survey. The survey took approximately 10 minutes to complete and was made available from April 2021 until June 2021. This research was approved by Auckland University of Technology Ethics Committee on 5 March 2021 (AUTEC reference number 21/22).

## Section 2.1: Procedures

Participants completed the anonymous survey comprised of 79 questions, including an optional nutrition and ED section comprised of 13 questions. Survey questions were delineated into three sections: 1) the MC characteristics section, 2) the perception of MC effects section, and 3) the nutrition and ED section. The MC characteristics section included questions about period regularity and MC symptoms, timing, and severity. The perception of MC effects section included questions about perceived positive or negative effects on performance, their timing, and severity. The nutrition habits and ED section included questions on calorie tracking habits, calorie restricting habits, ED diagnoses, and BID.

## Section 2.2: Participants

Participant inclusion criteria were females aged 18-50 who had not experienced menopause, who participated in full-body resistance training, trained at least twice weekly, and had at least a two-year training history. These qualifiers meant that most participants in this survey had a high level of resistance training experience. Participants who considered themselves competitive-level athletes were asked to self-identify as such, the criteria being that they actively competed in a RT-based sport, which included Olympic Weightlifting, powerlifting, CrossFit, throwing sports, physique-based competitions, and other related strength-based sports, regardless of their level of competition or experience. Those who self-identified as competitive-level were separated for certain analysis purposes and were labelled as competitive athletes and compared to the other participants who were labelled as recreational athletes.

## Section 2.3: Statistical analyses

Descriptive data, including means, frequencies, standard deviations (SD), percentages, and ranges, were reported for each section to establish normative data in this population. Chi-square tests were used for group comparisons, specifically for analysing differences in competitive athletes compared to recreational athletes for calorie tracking, BID, EDs, and MC characteristics for categorical data. Chi-square tests were also implemented to explore the relationships between BID and EDs with MC characteristics. Effect sizes were calculated with Cramer's V. Effect sizes which were reported with degree of freedom of 1 are qualitatively described as follows: $\geq 0.1$ represents a small effect, $\geq 0.3$ represents a medium effect and $\geq 0.5$ represents a large effect. For effect sizes with a degree of freedom of 2: $\geq 0.07$ represents a small effect, $\geq 0.21$ represents a medium effect and $\geq 0.35$ represents a large effect. Finally, for effect sizes with a degree of freedom of 3: $\geq 0.06$ represents a small effect, $\geq 0.17$ represents a medium effect and $\geq 0.29$ represents a large effect (Julie, 2020). Incomplete or missing data were excluded from the final analysis. The data set followed a normal distribution. Significance was set at the $p \leq 0.05$ level. All statistical analyses for this research were performed using JASP Team (Amsterdam, The Netherlands, 2023). JASP (Version 0.17) (https://jasp-stats.org/) computer software for Mac.

## Section 3: Results

## Section 3.1: Calorie Tracking and Calorie Restricting Habits

64.6% (n = 469) of participants reported tracking calories, with a slightly higher percentage of competitive athletes tracking calories 71.8% (n = 181) than recreational athletes. Competitive athletes were significantly more likely to track calories than recreational athletes (p = 0.003) with a small effect size (0.111). 81.3% (n = 617) of participants said they had purposefully dieted or restricted calories in the past two years. Competitive athletes gave a similar response of 83.7% (n = 220). When asked what the primary purpose of calorie restriction was, most participants selected weight loss for aesthetic purposes 58.8% (n = 356). Competitive athletes were less likely to select weight loss for aesthetic purposes 35.7% (n = 77), but weight loss for the purpose of a weight class-based sport was higher at 43.5% (n = 94). Most participants said they calorie restricted once a year or less, 43% (n = 260). There was no significant difference between competitive athletes and recreational athletes in their frequency of calorie restriction (p= 0.153). See **Table 4-1** for further information on calorie restriction and dieting habits.

Table 4-1 Nutritional Habits

| What is the purpose of your calorie restriction practices? | | | | |
|---|---|---|---|---|
| | Non-Athletes | | Strength Athletes | |
| | Percent | Count | Percent | Count |
| Weight loss for aesthetic reasons | 58.8 | 356 | 35.7 | 77 |
| Weight loss for weight class-based sport | 18.2 | 110 | 43.5 | 94 |
| Weight loss for general health | 11.6 | 70 | 6.5 | 14 |
| Weight loss for improved sport performance | 7.3 | 44 | 11.6 | 25 |
| Other | 4.1 | 25 | 2.8 | 6 |
| **How often do you attempt caloric restriction in a given year?** | | | | |
| Once a year or less | 43.0 | 260 | 41.7 | 90 |
| 2-3 times a year | 39.7 | 240 | 44.4 | 96 |
| 4-5 times a year | 9.9 | 60 | 6.5 | 14 |
| Other | 9.5 | 45 | 7.5 | 16 |

## Section 3.2: BID and EDs

BID prevalence was captured with the question, “How often are you dissatisfied by your weight/shape?” with the following answer choices: “Not at all”, “On occasion”, “Often”, “Almost all the time”. Participants answered “Almost all the time” 18% (n = 134), “Often” 25.4% (n = 189), “On occasion” 43.2% (n = 321), and “Not at all” 13.4% (n = 100) of the time. Competitive athletes were significantly less likely to answer, “Almost all the time” (p = 0.003) than recreational athletes with a medium effect size (0.14). ED prevalence was captured with the question, “In the past two years have you been diagnosed with an eating disorder?” most participants answered “no”, 95% (n = 700). Competitive athletes similarly selected “no” 95.6% (n = 248) of the time. All participants were then asked if they had any concerns that they may be developing an ED, to which 20.5% (140) answered yes.

## Section 3.3: The connection between BID and EDs with MC characteristics

There were no significant associations between BID and MC characteristics or most MC symptoms; see **Table 4-2** for further information. The presence of an ED and the MC characteristic amenorrhea were significantly associated (p = 0.01) with a medium effect size (0.293). Other MC characteristics and most other MC symptoms had no significant association with EDs. See **Table 4-2** for further information and Chi-Square test results.

Table 4-2 Chi-Square Test Results

| Questions | X2 | df | P-value | Effect Size |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| BID and strength athletes versus non athletes | 16.4 | 4 | 0.003 | 0.1 |
| BID and MC based mental health effects | 21.6 | 4 | 0.001 | 0.2 |
| BID and periods regular | 9.0 | 6 | 0.173 | 0.1 |
| BID and digestive issues | 26.1 | 4 | 0.001 | 0.2 |
| BID and MC length | 6.0 | 4 | 0.198 | 0.1 |
| BID and amenorrhea | 4.7 | 4 | 0.320 | 0.2 |
| BID and MC has negative impact on training | 13.3 | 4 | 0.010 | 0.1 |
| BID and cramps | 4.9 | 3 | 0.182 | 0.2 |
| EDs and strength athletes | 2.9 | 1 | 0.086 | 0.1 |
| EDs and amenorrhea | 13.6 | 2 | 0.001 | 0.3 |
| EDs and MC has negative impact on training | 0.6 | 2 | 0.755 | 0.1 |
| EDs and MC based mental health effects | 5.8 | 1 | 0.016 | 0.1 |
| EDs and digestive distress | 3.7 | 2 | 0.155 | 0.1 |
| EDs and periods regular | 1.5 | 4 | 0.832 | 0.1 |
| EDs and MC length | 0.185 | 2 | 0.912 | 0.1 |
| EDs and digestive distress | 0.9 | 1 | 0.336 | 0.1 |
| EDs and cramps | 0.08 | 1 | 0.928 | 0.0 |
| Strength athletes versus non-athletes calorie track | 8.9 | 1 | 0.003 | 0.1 |
| Strength athletes and caloric restriction frequency | 6.7 | 4 | 0.153 | 0.1 |
| Purpose of calorie restriction and periods regular | 5.3 | 2 | 0.071 | 0.1 |
| Frequency of calorie restriction and periods regular | 14.6 | 8 | 0.067 | 0.1 |
| Frequency of calorie restriction and MC has negative impact on training | 10.4 | 8 | 0.236 | 0.1 |

## Section 4: Discussion

The research aims of this survey were to establish the calorie tracking and restricting habits of RT athletes and to establish the relationship between BID and EDs with MC characteristics in this population. Further, a secondary aim was to compare the habits of competitive RT athletes with recreational-level RT athletes. Our principal findings were that calorie tracking may be more prevalent in RT athletes than in the general population [41]. Further, there were few significant associations between BID, EDs, and MC characteristics. Finally, competitive-level RT athletes answered similarly to recreational-level RT athletes in many questions, with some differences in calorie tracking prevalence, reasoning, and BID frequency and severity.

About 65% of participants tracked their calorie intake regularly, with competitive athletes significantly more likely to track calories. This is notably higher than previous research on the general population, which showed that 12.3% of young adult females [41] and 26% of female university students [42] tracked calorie intake using an app. Previous qualitative research has shown that calorie tracking can be beneficial in some contexts but also has the capacity to become an obsessive habit [43]. Although calorie tracking by itself may not be a cause for concern in this population, this habit has been associated with heightened ED severity and disordered eating behavior in the general population [41,44–46]. Further research is needed to establish the connections between calorie tracking and ED pathology in RT athletes.

Most respondents stated they restricted calories at least once in the past 2 years (81.3%), which is similar to previous research on aesthetic-based athletes, such as figure skaters and weight-class-based athletes, who regularly engage in calorie-restriction [1,47]. Most calorie restriction in the present survey was for weight loss for aesthetic reasons

(58.8%), even when physique athletes were removed (as it could be argued that for physique competitors, aesthetic reasons are also for the purpose of sport performance). The general population may feel societal pressure to meet specific appearance-based goals, which for many includes weight loss [16,20]; this may be a similar sentiment that RT females also experience, as was shown in the present survey results. Competitive athletes in the present survey, on the other hand, differed in their reason for calorie restriction; fewer cited aesthetic reasons (35.7%) for caloric restriction, and more cited competition in a weight class-based strength sport (43.5%). This finding demonstrates that RT athletes may differ from athletes of mixed sports, as RT athletes may be more concerned, on average, about weight-based shape or appearance than non-aesthetic-based athletes [16,48,49]. Thus, further research is needed to determine why and to what degree RT athletes may differ from other types of athletes, as this may indicate a higher risk for EDs among RT athletes.

In our survey 43.4% of participants reported experiencing BID “Often” or “All the time”, which is lower than some research on mixed sports athletes, where 50-83% of surveyed athletes reported BID [48]. This difference in BID levels measured in previous research could be due to different question phrasing, or may be representative of differences in sport type, age, competitive level, or the cultural background of the participants surveyed. Competitive athletes in the present survey were significantly less likely to experience BID “often” or “all the time” than recreational athletes. This finding contrasts with previous research that shows athletes at higher competitive levels, and athletes in general, have a higher likelihood of BID than the general public [50,51]. However, not all research agrees, as some data indicate lower levels of BID among athletes than non-athletes [51]. These contrasting findings may indicate that BID differs by sport type and level of competition.

In this survey, a low level of participants (5%) had been diagnosed with an ED, which is lower than previous research on the prevalence of EDs in other athletes, which has ranged from 18-42% [20,49,52]. Differences could be due to different question phrasing or, once again, the athlete population, including sport type, age, competitive level, and cultural background. The question used in the present survey to establish EDs asked specifically about ED diagnoses. However, much of the previous research asks questions related to ED symptoms, indicating that phrasing can have a substantial impact on findings. Further, not all individuals with disordered eating patterns necessarily seek medical help which could result in a diagnosis. Competitive athletes in this survey had a similar prevalence of ED diagnoses as recreational athletes, which also matches rates reported in a literature review by Chapa et al. (2022).

This research demonstrated that BID measures had no significant relationship with MC characteristics, including cycle length and regularity. This aligns with previous research on college-level athletes [51] but differs from other research where a connection between BID and MC phase in the general population was established [25]. Based on these conflicting findings, further research is warranted to better elucidate the connections between BID and the MC in different populations.

ED diagnosis was significantly associated with amenorrhea, which aligns with previous research on REDs and the Female Athlete Triad [3,26] and fits with the current model of understanding in low energy availability and MC hormone regularity. Further, BID was associated with a negative perception of the MC's effects on training, but ED diagnosis was not. This is a novel area of exploration of this population, and further research is needed to establish associations between ED and BID with perceptions of MC effects. Both high BID and the presence of EDs were significantly associated with MC symptom-based mental health concerns. Moreso, the most frequently cited mental health issues connected to the MC were anxiety and depression, which is supported by previous research linking mental health conditions such as anxiety and depression with BID and ED [23,50–52]. Mental health and its connection with the MC are essential areas of research that warrant further investigation, especially concerning BID and EDs in the RT population, which to date is relatively understudied.

## Section 4.1: Limitations

This survey has an inherent memory recall bias that may limit the accuracy of our findings. Since the focus of this survey was to explore the relationship between BID and EDs with the MC, rather than to investigate in-depth levels of BID or signs of EDs, the conclusions surrounding BID or ED prevalence in this population are also limited. To keep this survey at a reasonable length and focused on MC characteristics and other training-based data, we did not use longer form, validated measures for BID. Similarly, the primary question utilized for EDs was a question which asked if participants had received an ED diagnosis without other questions about symptomology as, again, this was not the primary focus of this survey and length was a concern. Specific ED classifications were also not isolated. Therefore, all ED diagnoses were analysed as one data point in this survey, which is a limitation, as some EDs may not be related to amenorrhea, which potentially influenced our findings. This data should be viewed as exploratory data for BID and EDs in this population.

## Section 5: Conclusion

RT females exhibited a higher prevalence of calorie tracking than the general population. Competitive-level RT athletes were less likely to calorie restrict for aesthetic purposes than recreational athletes, but more likely to calorie restrict for the purpose of weight-class-based sports. There were limited significant associations between BID and MC characteristics or MC symptoms as well as between EDs and MC characteristics. However, there was a significant association between amenorrhea and EDs, which aligns with previous research in this area. Both BID and EDs were significantly associated with MC-based mental health effects; this is likely due to the interconnected nature of mental health concerns like depression and anxiety. Future research that uses validated questions to establish BID and ED prevalence is needed to expand on this survey. Moreso, active MC hormonal monitoring in RT females would be an important step to move beyond the memory recall limitations of survey data. Such monitoring studies should have a focus on mental health effects, which would allow clearer relationships between BID, ED, and MC effects in the RT population to be established.

# Chapter 5 Menstrual cycle patterns and their relationship with measures of well-being and perceived performance metrics in competitive and recreational resistance-trained athletes

*Published in the Journal of Sports Medicine and Physical Fitness*

## Prelude

Chapter 2 outlined the lack of data on normative MC characteristics in athletic women, as well as the poor methodological quality of many studies in this field. Chapters 3 and 4 provided preliminary normative data on the MC characteristics of RT females, in addition to data on their perception of MC symptoms and their symptoms' impact on performance based on memory recall. However, more closely monitored data was necessary to objectively capture aspects such as MC regularity and MC effects on well-being. Therefore, the purpose of Chapter 5 was to monitor MC symptoms, characteristics, measures of well-being, and perceived performance metrics in a cohort of RT females while monitoring hormonal changes to better elucidate the prevalence, time course, and impact of MC symptoms.

## Section 1: Introduction

The menstrual cycle (MC) is a reoccurring series of hormonal changes that transpire approximately every 21–35 days in reproductive-age females[49]. This repeating rise and fall pattern is divided into different phases corresponding to unique hormonal fluctuations across the days of the MC [5,49]. The MC starts in the follicular phase, marked by the initial shedding of the menstrual lining from the previous cycle. The follicular phase is dominated by estrogen and the preparation of the follicle, which will be primed for release during ovulation [5]. The release of the matured egg from the ovary signifies ovulation, and after ovulation occurs, the luteal phase begins. The luteal phase is characterized by the corpus luteum releasing the dominant hormone during this phase, progesterone, from the ruptured follicle, which prepares the body for a potential pregnancy. If there is no fertilized egg, the luteal phase ends, and a new MC begins again [45]. This process repeats cyclically throughout the reproductive years, and some wonder if this process and the associated hormonal changes impact sports performance [15].

The main vital signs are respiratory rate, heart rate, temperature, and blood pressure [136]. To demonstrate the importance of the MC as a biological indicator of endocrine and metabolic health, there is a move to view MC as the fifth “vital sign” during reproductive years [45,137]. For the purposes of this research, the term regular has been used to classify a MC that meets the criteria in cycle length and is ovulatory. However, not every person who experiences a MC has a “regular” cycle every month, and MC irregularities (such as cycles that are too short or long in calendar days) are common, ranging from 10–50% of cycles depending on the population studied [19,49,138]. Most irregular menstrual cycles result in an anovulatory cycle, leading to a lower level of progesterone and therefore creating a different hormonal environment than the regular MC [19].

Menstrual symptoms, ranging from mild to debilitating, are common, and can severely affect job productivity and overall quality of life [6,7]. A range of MC symptoms and experiences are common; some of the most noted physical symptoms include menstrual cramps (dysmenorrhea), lower back pain, headaches, and bloating [11,12]. In addition, the MC appears to affect other physiological and psychological aspects of overall well-being or health makers otherwise seen as secondary. Specifically, sleep quality, resting heart rate (RHR), muscle soreness body image, mood, and perception of stress have all been connected to phases of the MC [11,80,112,139].

There is mixed evidence on how the MC affects sports performance, with many clinical studies and literature reviews showing variations in performance during different phases of the MC [17,106,140]. In conjunction with the evidence from experimental studies, many women report in surveys and qualitative research that they perceive their performance is affected by the hormonal changes from their MC [11,12,79]. Despite both experimental and observational studies indicating a negative impact due to menstrual-related changes or symptoms, some evidence suggests the MC's effects on performance may be trivial [13], or the findings are simply too ambiguous to be attributed to the MC itself [4]. This discrepancy in research is often attributed to methodological differences or unclear patterns between and within subjects' MCs [13,35,106]. To better clarify the impact of the MC on performance, more data are needed on normative athlete MC characteristics and the degree of inter- and intra-individual MC variation. These variations may elucidate the discrepancies shown across previous studies and may differ among athletic disciplines. Since there are distinct hormonal differences in irregular cycles, it is also important to establish the frequency of irregular cycles within a given population. Likewise, it is necessary to establish the patterns of MC symptoms and how the MC is associated with aspects of well-being; each of which may shed light on the actual effects of the MC on sports performance.

One of the fundamental issues in establishing the effects of the MC is that many studies do not accurately monitor the various hormonal changes associated with the varying phases of each cycle and do not take the different phases and transitions of the MC into account [10,13]. When researching MC effects, the primary focus is to observe any changes that occur in concurrence with the rise and fall of estrogen and progesterone, therefore it is crucial to establish if these hormonal changes are indeed occurring. This can be done by actively monitoring for a regular MC throughout a study. Previous literature has established research protocols for the sport science fields which utilize a combination of different MC monitoring techniques to accurately assess a regular cycle [26]. Specifically, daily basal body temperature (BBT), luteinizing hormone (LH) strips, and serum blood draws can be used in conjunction with calendar counting to accurately assess cycle regularity [26]. Combining these methods of hormonal monitoring with well-being, and training performance monitoring may help establish the interrelated impacts of the MC and its related symptoms on athlete training.

Finally, there is a notable gap in the literature regarding the impact of the MC on resistance-trained (RT) females and on their normative MC characteristics. Therefore, this exploratory study was designed to investigate MC characteristics and symptoms in RT athletes, to examine associations between measures of well-being and perceived performance across the MC. More specifically, we sought to answer the following research questions in eumenorrheic RT females: What is the average length of the MC and most common MC patterns? What is the frequency of irregular cycles and MC symptoms? How do measures of well-being, and perceived performance change across the MC?

## Section 2: Methods

A longitudinal monitoring study was implemented to capture data on MC characteristics, symptoms, changes in measures of well-being, and changes in perceived performance across the MC. Participants entered data via daily check-ins in the WILD.AI app (Wild Technologies AI Limited, London, UK) over the course of three cycles. A unique research format of the app was created, and participants were given a code that switched the app view into research mode. The research format of the app consisted of data logging sections, including the ability to log a daily check-in for MC symptoms, measures of well-being, and perceived performance metrics. The specific questions participants answered daily as they were asked in the app is available in the supplementary material. The research format of the app did not include any of the information from the commercial version of the app, such as recommendations for training.

A pilot study was performed with a convenience sample of five participants from the target population that completed the entire study protocol before the full data collection. The pilot study was conducted to ensure there were no issues with app use, compatibility, or overall study feasibility. Any changes from this pilot period were integrated into the final study design, but the data from the pilot period was not used for final analysis.

## Section 2.1 Participants

Participants were recruited via social media as this was the most feasible recruitment method during COVID-19. A recruitment poster was distributed via two of the authors' Instagram pages. Respondents to the social media posts were emailed the consent form, detailed information about the benefits and risks of study participation, study procedures and aims, frequently asked questions about participation, and a passcode to download the research app to preview it prior to consenting to the study. Seventy-five individuals responded to the social media posts, 44 responded to the follow-up email, and of those 44 respondents, 10 chose not to participate after receiving the study information packet, or self-identified as not meeting the inclusion criteria. A sample size calculation determined that 40 participants were needed, but due to COVID-19 lockdowns, further participant recruitment was not an option. More information about recruitment limitations can be found in the limitations section. Participants officially joined the study by signing and submitting the consent and information forms to the lead researcher. Inclusion criteria were performing resistance training over at least the past two years at least two times per week, which included the full body, for competitive strength sport or recreationally and having at least a one year history of a MC without hormonal contraceptive use. Exclusion criteria were current hormonal contraceptive use in any form, amenorrhea in the past year, known history of endocrine disorders or related gynaecological conditions, or injuries or illnesses that prevented regular training.

Once the consent form was received, the lead researcher scheduled a one-on-one interview to go over the details of the study. During the interview, the lead researcher ensured the individual met the inclusion criteria, understood participation commitments, reviewed the app use, the BBT procedures, the LH test strip procedures, the blood draw procedures, workout data entry procedures (outlined in Procedures below), and answered any questions the participants had. During this interview, participants were provided with specific instructions on how to interpret and respond to all daily check-in and workout questions, including the subjective well-being measures. Participants were instructed to keep all training, hydration, nutrition, and sleep habits as they usually would while enrolled in the study. Participants officially began the study on the first day of their menstrual period of their following cycle and stayed enrolled in the study for three cycles.

Thirty-four participants were recruited. Twenty-eight participants were enrolled from New Zealand; however, during the study, multiple full-country COVID-19 lockdowns occurred, causing difficulties in maintaining enrolment with sufficient participants. To increase participation, participants from other countries were invited to join, and six from the USA and UK also completed the study. Participants' mean age was 32 ± 7.2 years, and participants' mean age at menarche was 12 ± 1.2 years. All participants confirmed they had not used hormonal contraceptives for at least the past six months and that they perceived they had a regular menstrual cycle, with no occurrences of amenorrhea in the past year.

During the study seven participants suffered injuries, illnesses, or major life changes that prevented regular training and either self-elected or were asked to discontinue the study. The data from these seven participants were not included in the final analyses. There were also two participants who completed the full study, but upon final review of their data, they had not completed at least 80% of entries for all three cycles, therefore not meeting the minimum data entry requirement. The data from these two participants were not included in the final analyses either, leaving 25 participants' data for final analyses.

The participants' sport participation was as follows: CrossFit 40% (n = 10), powerlifting 20% (n = 5), general resistance training for fitness 16% (n = 4), Olympic weightlifting 12% (n = 3), strongman/woman 8% (n = 2) and physique 4% (n = 1). Eighteen of the 25 participants were actively competitive in their sport during the time of data collection, competing at the regional, national, or international level.

Recruitment for the study started in August 2021, and data collection concluded in December 2022. This research was approved by the Auckland University of Technology Ethics Committee on 17 June 2021 (AUTEC reference number 21/22).

## Section 3: Procedures

## Section 3.1: MC characteristics

MC characteristics were measured by calendar days counting cycle length, number of menstruation bleed days (logged in the app as none, light, medium, heavy), LH test strip procedures, BBT monitoring, and serum blood draws. MC regularity was determined based on a multi-method strategy per recommendations in previous literature, as one method alone does not provide sufficient cycle information to determine MC regularity [26]. Each cycle had to meet the regular cycle criteria for each of the three methods (calendar counting, BBT rise, LH strip positive) to be considered regular.

The calendar counting method was used to determine if the number of days of the cycle fit within the regular MC threshold between 22–35 days [26,49]. This was assessed based on the start of the menstrual period dates of each cycle for each participant.

BBT was used to assess changes in oral temperature due to the thermogenic effect caused by the rise of progesterone during the luteal phase. This method can be 90% accurate in determining if ovulation occurred when used in conjunction with other tracking methods [141]. Since the biphasic temperature rise signals a regular MC with a predicted elevation of progesterone, it can be assumed that the cycle was ovulatory [141,142]. Participants were supplied with an oral thermometer with a sensitivity to the 100$^{th}$ of a degree (Easy Healthcare Corporation, Illinois, USA) and instructed to take their temperature each morning at the same time upon waking before consuming food or fluids. Temperatures were recorded daily in the app. All BBT data was analysed using temperature maps to determine if a biphasic temperature rise of at least 0.3°C in the later part of the cycle occurred. Each BBT map for each cycle for each participant was analysed for a clear biphasic response; any cycle that did not meet this requirement was classified as irregular.

Participants were provided with LH test strips for three cycles with a sensitivity to LH at 25ml/u (Easy Healthcare Corporation, Illinois, USA) and instructed to follow the provided manufacturer's instructions and insert the test strip into a urine sample each day during their estimated fertile window. LH test strips are minimally invasive and directly indicate the LH surge which typically occurs within 24 hours of ovulation, signalling a regular MC [26,143]. Participants were instructed to start using the LH test strip daily from day 9 of their cycle until a positive result was recorded or told to stop using the test strips at day 24 of their cycle if no positive test was recorded.

Serum progesterone analysis via an intravenous blood draw to analyse progesterone concentration is the gold standard for analysing MC regularity in research settings (de Jonge et al., 2019). Participants were asked to complete one blood draw during their final cycle of participation (only one cycle was selected rather than all cycles, due to cost and participant time commitment). Participants were instructed to go to a pathology laboratory (Asia Pacific Healthcare Group, New Zealand) on day 21 of their cycle, where a phlebotomist performed a blood draw. The blood sample was then analysed with the Roche progesterone assay (F. Hoffmann-La Roche Ltd, Basel, Switzerland) to determine if the established progesterone minimum threshold of 16 nmol·L−1 was met during the latter part of the MC for it to be deemed regular [33].

In totality, regular cycles were confirmed by analysing the combination of calendar days, LH strip results, and BBT results. Additionally, for the final cycles where a blood progesterone sample was taken, the combined analyses of cycle regularity were compared with the blood draw results to ensure the accuracy of the other methods for determining cycle regularity.

## Section 3.2: MC symptoms

MC symptoms were tracked daily in the app. Participants gave a score of none, mild, moderate, or severe for each of the following symptoms during their daily check-ins in the app: bloating, headache, low back pain, and uterine cramps.

## Section 3.3: Measures of well-being

Measures of well-being for the purpose of this study were selected based on previous research, including both physical markers and psychological aspects that had a relationship with the MC [67,112,144–148]. Subjective measures of well-being were captured with daily self-reported in-app metrics. Participants were asked to rate their mood, body image and sleep quality for the previous 24 hours as “poor”, “okay”, or “great”. Participants were also asked to report the presence and severity of mood swings, soreness, and stress – rating them each day as “none”, “mild”, “medium”, or “high”. RHR was measured as beats per minute and recorded using the participants’ personal wearable fitness devices, (which all participants had) which included Apple Watch (Apple Inc., Cupertino, CA, USA), Garmin watch (Garmin, Olathe, KS, USA), or Fitbit (Fitbit Inc., San Francisco, CA, USA). These data were synced directly to the data collection app. Data entry was confirmed each day that a participant was enrolled in the study, and participants received reminders from the lead researcher if there were any issues with data entry.

## Section 3.4: Training sessions

Participants were asked to maintain their normal training routine while enrolled in the study but to ensure they incorporated one main full-body lift at least two times weekly for the duration of the study for the purpose of tracking load intensity during the study. For most participants, this was a squat, deadlift, bench press, or snatch exercise, depending on their training background. Upon entering the study, participants were asked to provide a full training plan to ensure they used at least a 10-repetition maximum (10 RM) load with their specified main lift at least twice per week, based on estimated proximity to failure (described below). Ensuring participants trained with reasonably high loads in their regular training was done to ensure that subsequent estimations of one-repetition maximum (1RM) based on training logs were more accurate for analysis. Participants entered their training notes into the app each time they trained throughout the study. At the end of each training session participants recorded session rating of perceived exertion (RPE), a validated method of capturing training load and session difficulty for most sports and athletic populations [149,150]. Further, participants recorded scores on the perceived recovery status scale (PRS), which is a valid, practical method to identify physical recovery and indicates one's performance expectations [151]. Finally, participants reported their perceived repetitions in reserve (RIR) – a validated scale for assessing proximity to failure upon set termination [152], – following their hardest set on their main lifts. Using the RIR information and notes included on the load used, an estimated 1RM was calculated for every training session for their main lift when a 10RM load or heavier was recorded using the previously validated Brzycki equation [153]. For example, if a participant completed five repetitions with 100 kg and reported an RIR of two repetitions, seven repetitions with 100 kg would be entered into the Brzycki equation to provide an estimated 1RM.

## Section 3.5: Statistical analyses

Descriptive statistics, including means, standard deviations, percentages, ranges, and frequencies, were used to describe participant demographic information, MC regularity, and MC characteristics. To examine the association between the current day of the cycle and each symptom (bloating, headache, lower back pain, uterine cramps), and each well-being outcome (body image, mood, stress, sleep quality, mood swings, soreness), a series of generalized linear mixed models were used. Each symptom and well-being outcome was dichotomized as present or not present each day and treated as a binary dependent variable (separately). Each model was fit using the *lmerTest* R package [40], using a binomial distribution and logit link function. Current day of the cycle was specified as a 3rd order polynomial fixed effect to allow the association with symptoms to vary over time. Participant was specified as a random intercept to account for each participant's repeated measures. The statistical significance of each fixed effect was tested using Type II Wald chi-square tests, with statistical significance set at $p \leq 0.05$. For each model, the adjusted ICC (interpreted as the proportion of variance explained by the participants' repeated measures), and the conditional $R^2$ (interpreted as the proportion of variance explained by the fixed and random effects) were calculated using the *performance* R package [41]. Next, estimated means, in the form of predicted probabilities (and 95% confidence intervals) were estimated using the *ggeffects* R package [42]. Finally, model assumptions were visually inspected using the *performance* R package [41]. A similar process was followed for the continuous outcomes (RHR, RIR, RPE and PRS), except a linear mixed model was fitted. All analyses were performed in R version 4.2.2. R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. (URL https://www.R-project.org/).

## Section 4: Results

## Section 4.1: MC characteristics

The average cycle length among all participants was 27.3 ± 2.72 days. The shortest recorded cycle was 20 days, and the longest was 36 days. The average variation in cycle length across the three cycles was 3.9 ± 2.13 days. The largest variation in cycle length for any participant was seven days (20% of participants experienced this level of variation), while the least variation in cycle length was one day (12% of participants). The average number of days of menstrual period bleeding was 4.1 ± 1.34 days. The shortest recorded menstrual period bleed was one day, and the longest was nine days. Across the three cycles, the lowest amount of variation in menstrual period bleeding length for a given participant was zero days (12% of participants), and the highest amount of variation was four days (12% of participants). See **Table 5-1** for further cycle length results.

Table 5-1 Cycle length

| Variable | Mean | SD | Min | Max |
|---|---|---|---|---|
| Cycle length mean | 27.3 | 2.72 | 21.0 | 33.3 |
| Cycle length min | 25.1 | 2.39 | 20.0 | 29.0 |
| Cycle length max | 29.0 | 3.24 | 22.0 | 36.0 |
| Cycle length range | 3.8 | 2.13 | 1.0 | 7.0 |

Overall mean, SD, minimum and maximum length in days for the entire sample.

## Section 4.2: MC regularity

Regular versus irregular cycles were categorized based on a combination of BBT, LH strip results, and cycle length in days. All three criteria had to be met for a cycle to be considered regular (if not met, it was considered irregular). Seventy-five cycles were recorded by the 25 participants; 12 had insufficient cycle regularity data (BBT entries, or LH strip entries missing) and were not analyzed, 44 were regular (69% of analyzed cycles), and 20 were irregular (31%). The most common reason for an irregular cycle classification was a lack of biphasic rise on the BBT map (10 cycles; 16%). Seven cycles (11%) were considered irregular due to a lack of positive LH strip test results (4 of which were in conjunction with an irregular BBT map). Seven participants (28%) experienced regular cycles for all three recorded cycles. Seven participants (28%) recorded only one regular cycle. All cycles with an associated blood draw (11 cycles) met the progesterone criteria for a regular cycle and had a corresponding BBT result, LH strip result, and cycle length that matched the regular cycle results shown in the blood draw.

## Section 4.3: MC symptoms

Table 5-3 shows the average number of days each MC symptom was experienced per participant.  Across all cycles, most recorded symptoms were listed as mild to moderate severity. Across all symptoms, less than 1% of all recorded entries were listed as severe across any recorded cycle. The highest probability for experiencing bloating and low back pain was at the beginning and end of the cycle, as indicated by the model-estimated probabilities (Figure 5-1). Headaches and uterine cramps were most notable at the beginning of the cycle. Bloating had the highest model ICC, suggesting that the within-participant patterns explained a large proportion of the variation in bloating outcomes. Contrastingly, uterine cramps had the lowest ICC, suggesting a more even spread of symptoms across participants. Table 5-4 presents results from the generalized linear mixed models, indicating which symptoms are significantly associated with the day of the cycle.

Table 5-2 Number of days each MC symptom was experienced per cycle

| Variable | Mean | SD | Min | Max |
|---|---|---|---|---|
| Bloating | 6.0 | 6.73 | 0 | 29 |
| Headache | 5.0 | 6.25 | 0 | 32 |
| Lower back pain | 4.2 | 4.39 | 0 | 21 |
| Uterine cramps | 3.1 | 2.59 | 0 | 18 |

Table 5-3 The percentage of participants that experienced MC symptoms

| Percentage of Participants | n | Percent |
|---|---|---|
| Bloating | 22 | 88.0% |
| Headache | 23 | 92.0% |
| Low back pain | 21 | 84.0% |
| Uterine cramps | 24 | 96.0% |
| **Percentage of Cycles** | | |
| Bloating | 60 | 81.1% |
| Headache | 58 | 78.4% |
| Low back pain | 52 | 70.3% |
| Uterine cramps | 65 | 87.8% |

The percentage of participants that experienced MC Symptoms (across any of their three cycles) compared to the percentage of cycles where these symptoms were observed, showing that not all participants experienced the same symptoms every cycle.

Table 5-4 Results of the linear mixed models for each outcome variable

| MC Symptom | P | ICC | R 2 | SE |
|---|---|---|---|---|
| Bloating | <0.002# | 0.52 | 0.55 | 0.03 |
| Headache | <0.002# | 0.46 | 0.47 | 0.04 |
| Low back pain | <0.002# | 0.46 | 0.48 | 0.03 |
| Uterine cramps | <0.002# | 0.25 | 0.52 | 0.04 |
| **Measures of Well-being** | | | | |
| Body Image | <0.002# | 0.64 | 0.64 | 0.04 |
| Mood | <0.002# | 0.21 | 0.25 | 0.04 |
| Sleep quality | 0.003 | 0.16 | 0.17 | 0.04 |
| Mood swings | <0.002# | 0.47 | 0.51 | 0.04 |
| Stress | 0.002 | 0.61 | 0.62 | 0.03 |
| Soreness | 0.006 | 0.35 | 0.35 | 0.02 |
| RHR | 0.001 | 0.78 | 0.79 | 0.11 |
| Performance | | | | |
| Session RPE | 0.078 | 0.17 | 0.18 | 0.06 |
| 1 RM | 0.016 | 0.89 | 0.89 | 0.65 |
| PRS | 0.004 | 0.18 | 0.20 | 0.05 |

# = p < 0.0002. Showing the p-value, intraclass correlation coefficient (ICC), R-squared (R 2), and standard error (SE). These results are shown here numerically and also represented in the figures below.

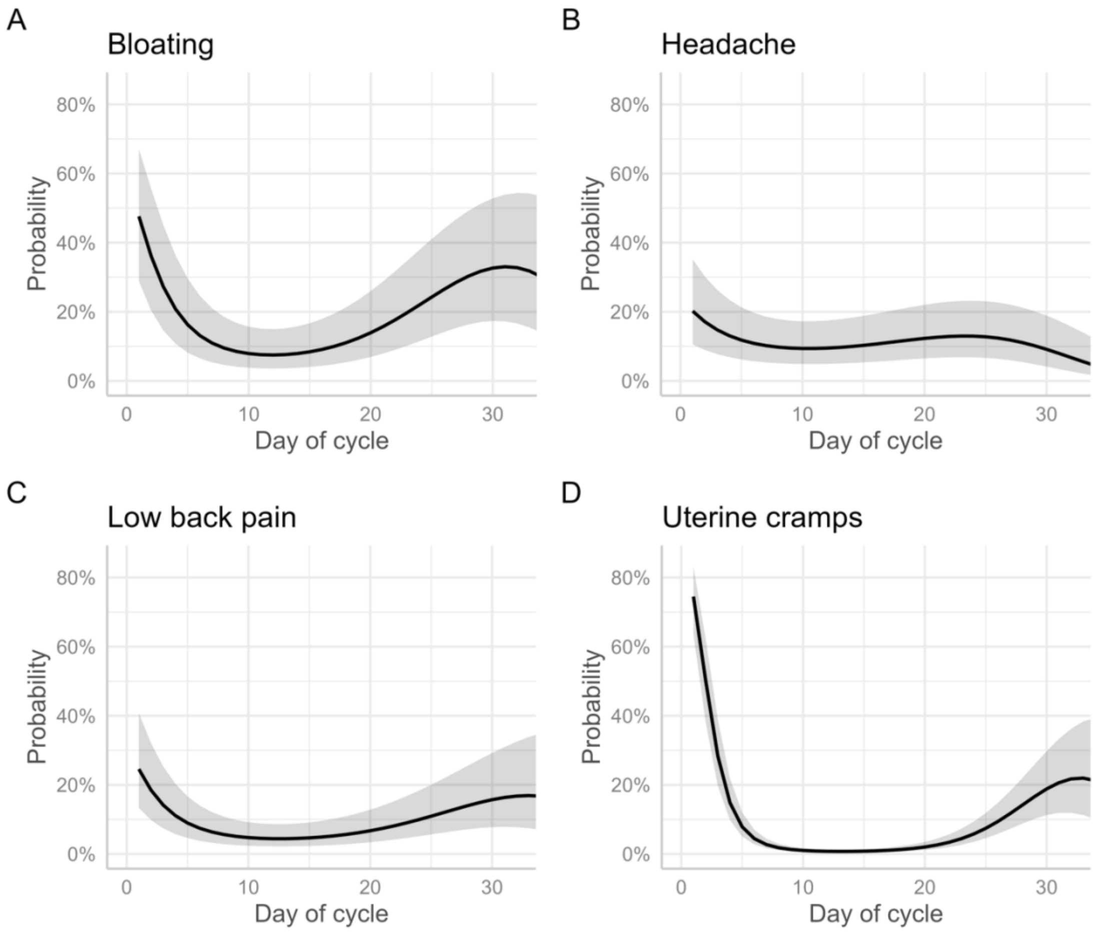


Figure 5-1 Predicted probabilities of experiencing symptoms across the MC.

Figures 5-1 to 5-3 Legend: These graphs show the model-estimated means, represented as predicted probabilities (black line) with 95% confidence intervals (grey shaded ribbon), for each variable. These estimates were obtained from linear mixed models, with a binomial distribution and logit link function.

## Section 4.4: Measures of well-being

The highest probability of experiencing poor body image was at the beginning of the MC (Figure 5-2). Higher probabilities of experiencing poor mood, mood swings, poor sleep, and stress occurred both at the beginning and end of the MC. There was a trend towards a slightly higher RHR at the end of the MC (Figure 5-3). Poor sleep quality had the lowest ICC (Table 5-4), whereas body image, stress, and soreness had the highest ICC, indicating these outcomes were more participant-dependent.

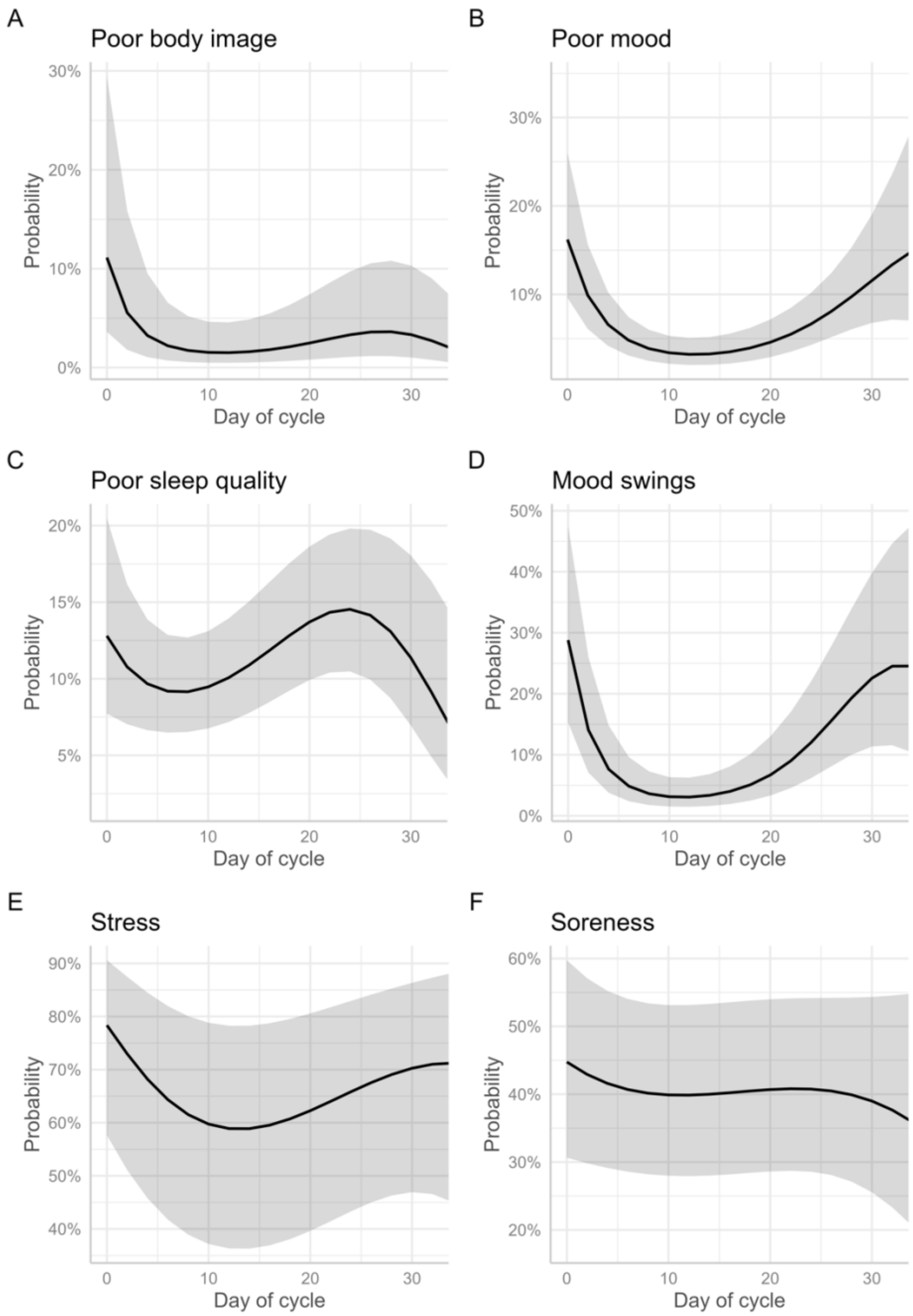


Figure 5-2 Predicted probabilities of experiencing measures of well-being.

## Section 4.5: Performance

PRS tended to be lower at the start and end of the MC with a low amount of participant variation. The substantial individual variation for estimated 1RM across the cycle with a general trend of 1RM decreasing towards the end of the MC for most participants. There was no significant association between session RPE and the day of the MC. See Table 5-2 and Figure 5-3 for further information on the linear mixed model results for the perceived performance metrics and estimated 1RM.

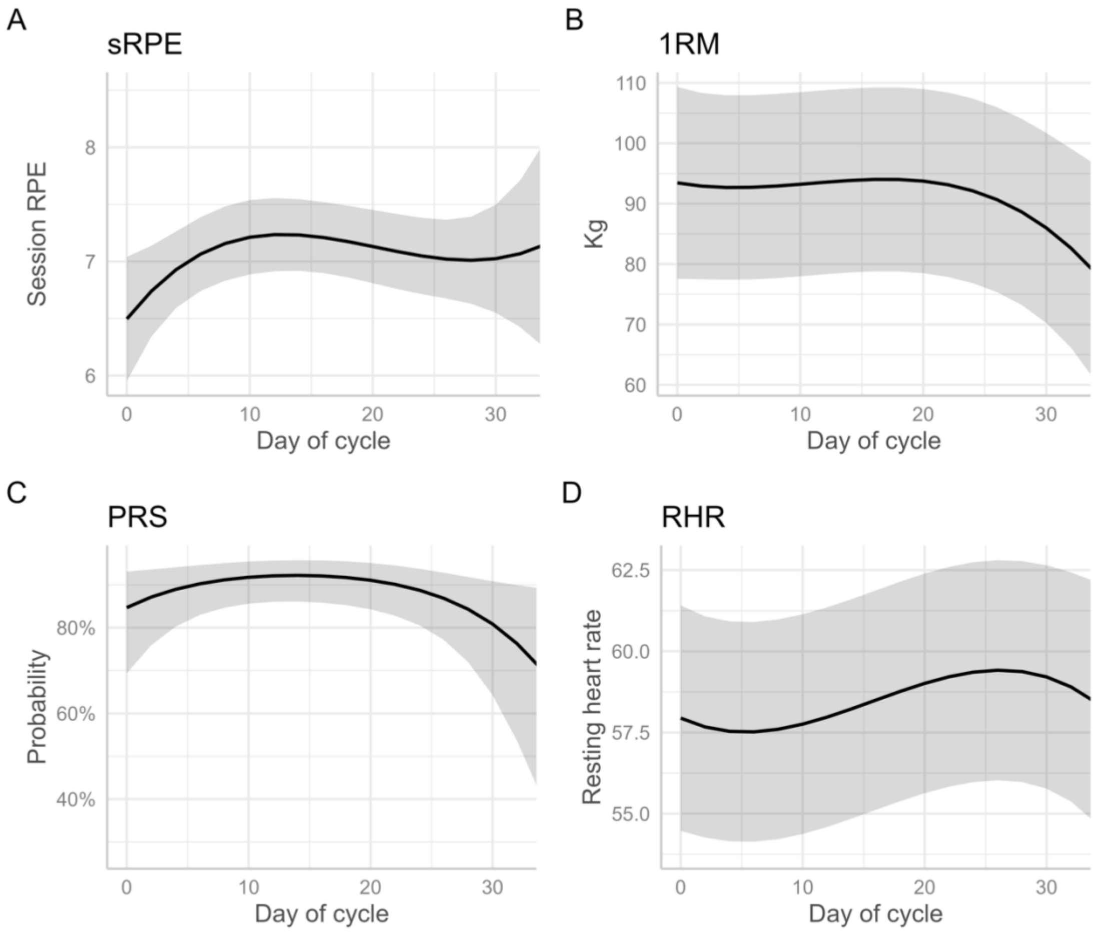


Figure 5-3 Estimated means of perceived performance metrics across the MC

## Section 5: Discussion

The purpose of this exploratory study was to describe the normative MC characteristics and symptoms in a RT population, their time course, and determine if there were associations between measures of well-being, MC symptoms, and perceived performance across the MC. Most MC characteristics and symptoms in the present RT population aligned with previous research in the general population. However, the frequency of irregular cycles was higher than in previous research in the general population [8]. The amount of individual variation and cycle-to-cycle variation in MC characteristics and MC symptom prevalence was also high. All measures of well-being were significantly associated with specific days of the MC, demonstrating a change in well-being probability based on the timing of the MC. Among the performance metrics, both estimated 1RM and PRS were significantly associated with days of the MC, but session RPE was not, showing that some perceived performance metrics may be associated with changes of the MC, but not all.

The average MC length in this study was comparable to previous research on the general population, most (65%) cycles lasted 25-30 days [1]. The average menstrual period length in this study was also aligned with previous research reporting an average of 3.9 ± 1.4 menstrual period days [1]. However, we observed a high degree of individual variation in cycle length, a finding not well documented in previous research. Although the average cycle data fell within comparable averages to prior data, 20% of participants had up to 7 days of cycle length variation across their three recorded cycles. While these variations fall within the established parameters of regular - albeit at the highest end [1] - this variability may have considerable practical implications when planning training around the MC or its symptoms, as their timing may vary by up to one week.

The frequency of irregular cycles in this study (31%) was higher than in previous research on the general population. Specifically, Jung et al., (2018) reported that only 14.3% of cycles were irregular in a sample of Korean women. In contrast, De Souza et al., 2010 found that nearly 50% of the cycles of exercising females were irregular; a proportion substantially higher than the present study. Likely, this difference is due to both hormonal monitoring methodology differences and potentially exercise type. Also of note, in the present study, only 28% of participants had a regular MC for all three recorded cycles, demonstrating that most individuals in this population may experience irregular cycles with some level of frequency.

MC symptoms in this study followed similar patterns to the general population and other athletic populations. All participants reported MC symptoms every cycle, similar to previous surveys, which report most participants experience at least one MC symptom most cycles [12,19]. In addition, the timing and type of MC symptoms in the present study were similar to prior data on runners and swimmers [43,44]. In alignment with previous research where 85% of exercising females reported cramping [11], menstrual cramps were experienced by nearly all participants (96%) in the present study. However, most participants recorded mild cramps in contrast with previous research on athletic populations who reported moderate severity on average [12].

Of note in the present study, there was a large amount of individual variation in the number of days MC symptoms were experienced, as well as a notable amount of variation in MC symptoms from cycle to cycle for a given individual. This high level of inter- and intra- individual variation may explain – at least in part – why the effects of the MC on sports performance are unclear in previous research [17]. Since, for some individuals, symptoms may be worse in certain cycles than others, the impact on performance likely differs as well from cycle to cycle. Although this concept of MC variation may further complicate the ability to research MC effects, it may be an essential component to ascertaining the actual MC effects on performance in the future.

Overall, this study found that all tracked measures of well-being were associated with specific days of the MC, showing that changes in the probability of experiencing a given measure change across the cycle. Many of the findings from our study on measures of well-being align with previous research on other populations. The association between poor body image and day of the MC matches previous research reporting an association between body image scores and the MC, with the highest level of body image dissatisfaction occurring during the menstrual period phase [14]. The findings from the present study on RHR align with previous research [31,32], where a significant association between MC phase and RHR in the general population was reported with an average increase in the luteal phase of 1.5 – 2.9 beats per minute. The association between MC day and poor sleep quality found in our study aligns with previous research on both mixed athletes and the general population, where an overall higher likelihood of poor sleep quality and lower sleep efficacy during the premenstrual and menstrual phases is often reported [34,45]. These similarities in findings are important to note in establishing the connection between MC effects and performance, as all the above variables may impact it, and may do so independently from hormonal changes in strength or capability.

Other findings on well-being from our study differed from the existing literature. While we reported an association between stress and specific MC days, contrasting research exists on football athletes, where there was no association between MC phase and reported stress levels [45]. Likewise, both mood and mood swings were associated with specific days of the MC in our study; this differs from previous research, which reported no association between changes in mood and the phases of the MC in both exercising women and the general population [32,46]. Finally, we observed an association between soreness and specific MC days, which also differs from previous research on exercising females, where there was no such association between MC phase and soreness [45,46]. Explanations for these differences may be due to variations in question phrasing or in the populations studied; but nonetheless, they are important avenues for future research to better elucidate and isolate MC hormonal effects.

Our study measured multiple metrics of well-being that are commonly associated with mental health (mood, mood swings, and stress), all of which showed a significant association with days of the MC, demonstrating that there is an increased probability for poor markers of mental health during the beginning and end of the MC, which aligns with previous research on athletic populations [11,12]. Authors of a previous study that investigated the effects of the MC in an untrained population concluded that MC-associated psychological effects were positively correlated with performance reductions, while hormonal fluctuations were not [29]. Mental health may be yet another critical component to investigate regarding the MC and its potential effects on performance, as concerns such as low mood or high stress, which are more likely to be prevalent during certain days of the MC in some individuals, have been shown in previous research to have effects on athletic performance outcomes [30,47].

The nonsignificant association between Session RPE and MC day we observed aligns with previous research in football and mixed athletes [15,45]. Thus, session RPE may be a consistent enough metric that it can be used to accurately determine the perceived difficulty of training sessions in athletic populations independent of MC phase. Our findings on PRS agree with previous research that also showed a reported lower level of perceived recovery during the latter part of the MC, which seems to align with our findings that estimated 1RMs were lower towards the latter part of the MC, and PRS scores were lower at both the beginning and end of the MC [45]. Reductions in performance may be related to issues like poorer sleep quality during these specific phases of the MC [13,33], and if so, targeting improved sleep hygiene may be a viable option for coaches and athletes.

Based on this exploratory study, many recommendations for future research can be made. First, it is essential that future research continues to investigate MC irregularity, as it may be a more common occurrence than previously thought and may not be evident from basic methods of MC monitoring alone, such as MC length. Furthermore, since irregular cycles appear prevalent in the RT population, it is also important to establish if irregular cycles affect RT performance differently than regular cycles. Future research that focuses on the role of the MC in athletic settings would benefit from taking mental health and well-being into account due to the potential for psychological status to impact performance. At this time, more research on the MC and resistance training performance is needed before training recommendations based on MC hormonal changes can be made for the broader population.

This research provides practical insight regarding the high inter- and intra-individual variability of MC regularity, associated symptoms, and their potential impact on performance and well-being. This variability should be considered both by coaches and athletes when assessing performance and training capacity. Since factors like mental health may affect sports performance [48], individuals who experience mental health-related MC symptoms should seek appropriate care and treatment. Overall, with the current evidence as it stands, an individualized approach should be taken for any training or performance considerations related to the MC.

## Section 5.1: Limitations

COVID-19 limited the scope of this project as lockdowns, gym closures, and participants becoming ill all caused lower participant recruitment than initially planned. All data for this study was collected remotely, which inherently has a higher likelihood of participant entry and recording error. With a small sample size and the inherent limitation of participant self-selection via social media recruitment for a MC-based research study, this sample is not reflective of the entire RT female population, and therefore conclusions cannot be applied broadly across all athletes but are instead a point of interest for further research in this field.

BBT collection methods in this study had a high rate of compliance issues, leading to many BBT maps having insufficient data to show any biphasic rise, affecting the ability to determine if a MC was regular or irregular. BBT also has inherent limitations in a study like this because there is an effect of age and environment [49] which are factors to consider in this study due to the wide variety of ages among participants and the varied geographic locations. There were also issues with LH strip interpretation among some participants, and for some participants, there were complexities in finding the correct time to take the LH test. LH secretion timing and the length of time of the surge in urine can differ from person to person and from cycle to cycle [21,50], which can make finding the correct time for participants to use the LH strips difficult to instruct without some trial and error. This factor may have led to some cycles being classified as irregular due to LH strip interpretation when a serum blood draw may have shown otherwise. COVID-19 lockdowns also created scheduling conflicts for participants, which resulted in a much lower percentage of compliance for serum blood draws than anticipated. Without regular serum hormonal monitoring, assumptions are made about cycle regularity and hormonal changes [22,24,51], which was the case in this study. In general, in MC research, phases are not well defined [24,51], and without close hormonal monitoring, any information on phases is an approximation, which is why direct MC phases were not used for comparison purposes in this research, and instead, a comparison of calendar days of the cycle without the explicit labeling of phases were used.

The daily check-in questions used for this study were simple, unvalidated, self-reported metrics that were convenient for participants to answer daily in the app setting. Since they are not validated metrics, specifically for the psychological aspects of well-being measures, they cannot be used to diagnose or draw specific conclusions about this population, but instead may be useful to indicate directions for future research.

Since this study only monitored the participants and was exploratory in design, there was a large variety in training styles, volume, and exercise choices. Therefore, the conclusions that can be drawn regarding performance are limited, and future interventional work is required to determine the consistency of these findings and the best course of action if coaches or athletes wish to alter the time course of the MC's impact on performance. To conclude, while the perceptual performance metrics and the estimated 1RMs we reported capture some valuable training information, to truly isolate the effects of MC phase on performance a standardized intervention would be necessary.

## Section 6: Conclusion

MC symptoms and characteristics in the present RT population were similar to the general public and other exercising females. MC irregularity was common and further research using hormonal monitoring techniques should investigate the prevalence of MC irregularity in varying athletic disciplines. Further, there is a high degree of individual variation in MC characteristics and symptoms, as well as variation from cycle to cycle, which may cause inconsistent performance patterns related to MC timing. Current established averages for MC characteristics and symptoms do not sufficiently account for the high degree of MC variation that exists. Finally, many measures of well-being are significantly associated with specific days of the MC, and, overall, there appear to be higher probabilities of low measures of mental health during the beginning and end of the MC.

# Chapter 6 A randomised crossover trial on the influence of a daily mindfulness yoga practice on menstrual cycle symptoms, measures of well-being, and training perception in athletic women

*International Journal of Yoga Therapy (In review)*

### Prelude

The previous chapters highlighted that MC symptoms vary substantially from person-to-person, and can be severe enough for some to meaningfully impact their well-being or perceived performance. Given that the most commonly used palliative interventions for MC symptoms often don't address all aspects of concern – notably both the psychological and physiological impacts - novel methods for symptom mitigation are needed. To explore one such method, Chapter 6 built on the research in previous chapters, including the Chapter 2 literature review, which identified that a mind-body intervention, such as yoga, may have the potential to mitigate MC symptoms. Therefore, Chapter 6 explores the use of an at-home, mindfulness-based yoga intervention for MC symptom mitigation. Specifically, in a crossover design, MC symptoms in a cohort of RT women were compared during one MC in which the participants performed a short, daily yoga practice, to a control MC where yoga was not performed.

## Section 1: Introduction

The menstrual cycle (MC) is a series of hormonal fluctuations that occur approximately every 22–35 days in reproductive-age women [1,2], often resulting in a range of physical and psychological changes at different points of the cycle that, for some, have debilitating effects [3,4]. MC symptoms can include menstrual cramping pain, low back pain, headaches, sleep disturbances, fatigue, mood disturbances, and changes in self-perception, including physical capability and commonly occur at the beginning or end of the MC [3,5–8]. Premenstrual syndrome (PMS) is a specific cluster of MC symptoms that includes both physical and psychological effects and occurs in the latter part of the MC, usually starting about one week prior to the menstrual period, and disappearing shortly after the onset of menstrual bleeding [9,10].

MC symptoms, including dysmenorrhea or period pain, can affect work and daily function for women over an extended period of their lives, and do not appear to improve with age, causing regular disruptions throughout the reproductive years [4,11,12]. The MC can also affect aspects of sports performance and, for some, the ability to train and exercise [13–16].

Current first-line treatments as recommended by guidelines for MC symptoms include analgesics and hormonal contraceptives (HCs) [17,18]. However, neither provide complete relief of symptoms [19]. Specifically, fatigue or mood disturbances, which are common, may not respond to this type of pharmacological treatment [8,20]. Additionally, HCs have side effects for many athletes [21], making this treatment option undesirable for some. A treatment modality that can address the broad range of bothersome symptoms, both physical and psychological, is currently lacking.

A potential intervention that may be able to address these symptoms is yoga, a mind-body practice that incorporates physical postures with breath work to foster a mindful connection to the body [22–26]. Yoga can balance the neuro-endocrinal axis [27,28], resulting in emotional improvements, including reduced stress and pain, while improving well-being [22,29,30]. Yoga can positively affect participants' PMS symptoms by boosting mood, reducing pain, improving sleep quality, and body awareness [27,28,31,32].

Previous research also shows that yoga benefits athletes by reducing injury risk and fatigue [33] and increasing balance and flexibility [34]. Despite the high prevalence of MC symptoms in athletes [3,5] and the positive effects of yoga on PMS symptoms, [28,35] there is no known published research on yoga as an intervention for MC symptoms in athletes.

Given the potential benefits for both improving PMS and reducing injury in athletes, the aim of this study was to determine the association between participation in a novel online daily yoga program and MC symptoms, measures of well-being, and changes to exercise perceptions in athletic females. Our research question was, "Does a short daily yoga protocol influence MC symptoms, measures of well-being (sleep quality, perception of stress, or mood), or measures of perceived training performance across the MC in athletic women?" The objectives of this study were to investigate the use of a yoga protocol in an athletic population for MC symptom mitigation.

## Section 2: Methods

## Section 2.1: Study design

This was a randomized crossover trial which, due to logistical constraints, was limited in sample size to 20 participants. This was dictated by feasibility, rather than a formal power calculation, as COVID-19 and related lockdowns limited our recruitment efforts. However, given that the yoga intervention was likely to result in small to medium effect sizes, this sample size is in line with recommendations for pilot and feasibility studies (Bell et al., 2018). Participants were enrolled for three MCs and completed a short daily yoga protocol for one full MC while answering daily questions about MC symptoms, well-being, and training performance, then answered the same questions for the other cycles without the yoga intervention. See **Figure 6-1** for study protocol information. The cycle order in which the yoga intervention was implemented was randomized, based on the order in which participants joined the study. Participants were assigned a code of either 1, 2, or 3 which indicated the MC in which they completed the intervention portion of the study. Given that the length of the washout period for yoga is unclear, outcomes following the yoga intervention cycle were compared to a control cycle, either the cycle before the intervention or their last enrolled cycle (rather than the direct subsequent cycle), to avoid potential lasting effects from the intervention. Of the 20 participants, seven completed the control cycle after the intervention.

## Section 2.2: Participants

To keep training conditions as consistent as possible among participants, women who primarily resistance trained at a recreational or competitive level were recruited. To be included, participants had to participate in full-body resistance training at least two times per week, with at least a two-year training history, and have at least a one-year history of a natural MC without HC use. Exclusion criteria were HC use in the last six months, known endocrine disorders or related gynecological conditions, amenorrhea in the past year, or injuries or medical conditions that prevented regular training and physical activity. All participants stated they had no prior involvement in consistent yoga practice.

Recruitment occurred on Instagram via informational posts on the authors' pages that had a combined reach of 33,599 accounts and received 35,778 impressions. Respondents to the post were given study information and consent forms to review. Those electing to participate had a one-on-one interview with the lead researcher to review the study's details (app use, data input, MC monitoring procedures, yoga protocol), entrance criteria, and answer questions. Participants officially began the study on the first day of their next menstrual period and were enrolled for three cycles. The intervention and control cycle protocols were adjusted to match the participant's unique eumenorrheic cycle and would start and stop with the onset of their menstrual period. For example, a participant would begin the intervention protocol on the first day of their menstrual period and then end the intervention when their next menstrual period began, resulting in a variable, individualized length.

Recruitment began in August 2021, and data collection concluded in December 2022. This research was approved by the Auckland University of Technology Ethics Committee on 17 June 2021 (AUTEC reference number 21/22).

### Section 2.3: Data collection

Participants entered data via a daily check-in on a smartphone application for all three cycles. Data was captured in a customized research version of the WILD.AI app (Wild Technologies AI Limited, London, UK). Interested participants were provided a code to download the research app so they could review it prior to enrolment. The research format of the app did not incorporate any features from the commercial version, such as training or symptom mitigation recommendations.

## Section 3: Procedures

### Section 3.1: Intervention

Based on data indicating that online yoga programs provide notable benefits and that telehealth yoga delivery during COVID-19 improved PMS symptoms (Brosnan et al., 2021), a 10-minute simple and concise, at-home daily yoga protocol was provided to participants via video to maximize adherence. A short yoga protocol was selected for this research since it is likely to be more manageable for many individuals to complete daily. In addition to step-by-step video guidance, participants were given a printout of each pose with descriptions.

The yoga protocol was created with the aim of increasing mindfulness and mitigating MC symptoms. The first author is a 200-hour registered yoga teacher who developed the yoga protocol. Yoga poses were selected based on protocols used in previous research on yoga for PMS treatment (Günebakan & Acar, 2023; Vaghela et al., 2019) and were designed to induce relaxation while utilizing familiar postures for athletes. In addition, the Yin style of yoga, which focuses on mindfulness via a quiet meditative style, was selected for its potential to reduce stress and anxiety (Lemay et al., 2021). Finally, other experts in yoga for research were consulted about pose selection. In order, the following poses were implemented: easy pose *sukhasana*, seated twist *parivrtta sukhasana*, butterfly *baddha konasana*, cat pose *marjariasana,* cow pose *bitilasana*, child's pose *balasana*, knees-to-chest pose *apansana*, supported bridge pose *setu bandha sarvangasana*, supine spinal twist pose *jathara parivartanasana*, and corpse pose *savasana*. Poses were held for one minute, and participants were instructed to focus on their breathing, physical movement, and the area of the body activated during the pose, rather than achieving a specific range of motion or pose perfection. Emphasis was made to stay comfortable by using pillows, bolsters, or other props. The practice finished with a one-minute guided meditative relaxation in the *savasana* pose, which participants were informed they could continue for as long as they wanted after the video ended.

## Section 3.2: MC monitoring

Participants tracked their MC characteristics, basal body temperature, and symptoms daily in the app to collect MC regularity data. The basal body temperature measurement was employed to evaluate alterations in oral temperature resulting from the thermogenic impact caused by the increase in progesterone levels during the luteal phase. When this method is utilized in combination with other tracking techniques, it has the potential to achieve a 90% accuracy rate in detecting ovulation and therefore MC regularity(de Mouzon et al., 1984). Luteinizing hormone strips with a sensitivity of 25ml/u (Easy Healthcare Corporation, Illinois, USA) were used during the ovulatory window to confirm ovulation. Luteinizing Hormone urine test strips are a minimally invasive method of directly detecting the luteinizing hormone surge, which typically occurs within a 24-hour timeframe prior to ovulation, indicating MC regularity (Miller & Soules, 1996). These measures (basal body temperatures and luteinizing hormone strip results) were analyzed in combination with the total cycle length to determine MC regularity, following the recommendations outlined in previous literature (de Jonge et al., 2019).

During enrollment, participants were advised to maintain typical training, hydration, nutrition, and sleep routines.

## Section 3.3: Daily check-ins

Each day for the duration of the study, participants would answer the same questions daily in the app about MC symptoms and training. The daily app check-in had questions on the severity of headaches, bloating, menstrual cramps, and low back pain. Participants reported “none”, “mild”, “moderate”, or “severe” for each symptom. Measures of well-being were also collected daily, and participants reported “poor”, "okay", or "great" for mood and sleep quality, while stress was scored as "none", "mild", "medium", or "high".

## Section 3.4: Training

Throughout the study period, participants were instructed to follow their regular training routine; however, they were specifically instructed to ensure their training included a minimum of two weekly sessions including a main lift, such as a snatch, squat, or deadlift. After each training session, participants recorded their session rating of perceived exertion (sRPE) in the app. sRPE is a validated method for capturing training session difficulty for most athletic populations (Foster, 1998; Haddad et al., 2017) scored on a 1–10 scale. An estimated one repetition maximum (1RM) for these lifts was determined based on repetitions in reserve (RIR) (the participant's estimation of proximity to failure following a set). Participants reported their RIR after their most challenging exercise set in the app. Since RIR is a validated measure for assessing proximity to failure in trained athletes (Helms et al., 2016), it was used in combination with the participants' training notes and the previously validated Brzycki equation (Dale LeSuer et al., 1997) to estimate 1RM.

## Section 3.5: Statistical analyses

Descriptive statistics, including means, standard deviations, percentages, and ranges were used to describe participant demographic information, MC characteristics, and protocol adherence rates. To determine if the association between each outcome variable and current day of the MC varied by cycle type (intervention cycle or control cycle), a series of general(ized) linear mixed models were used. The outcome variables consisted of symptoms (bloating, headache, lower back pain, menstrual cramps), well-being outcomes (mood, stress, sleep quality), and training outcomes (estimated 1RM, sRPE). Each symptom and well-being outcome was dichotomized as present or not present each day and treated as a binary dependent variable (separately). Each model was fitted using the lmerTest R package [47], using a binomial distribution and logit link function. The current day of the cycle and cycle type (intervention or control) were specified as fixed effects, along with their interaction. Current day of the cycle was specified as a 3rd order polynomial to allow the association with each outcome variable to vary over time. Participant was specified as a random intercept to account for each participant's repeated measures. The statistical significance of each fixed effect was tested using Type II Wald chi-square tests, with statistical significance set at $p \leq 0.05$. For each model, the adjusted ICC (interpreted as the proportion of variance explained by the participants' repeated measures), and the conditional $R^2$ (interpreted as the proportion of variance explained by the fixed and random effects) were calculated using the performance R package [48]. Next, estimated means, in the form of predicted probabilities (and 95% confidence intervals) were estimated using the ggeffects R package [49]. Finally, model assumptions were visually inspected using the performance R package. A similar process was followed for the continuous outcomes (sRPE and estimated 1RM), except a linear mixed model was fit. All analyses were performed in R version 4.2.2. R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. (URL https://www.R-project.org/).

## Section 4: Results

Eighteen out of the 20 participants completed the study with a mean age of 32 ± 7 years. Two participants opted out of study participation early due to injuries unrelated to the study; their data was not used in the final analysis. See **figure 6-1** for CONSORT diagram. The average MC length for the entire sample was 27 ± 3.7 days. 61% (n = 22) of all MCs were regular, although 22% of cycles (n = 8) did not have sufficient data to determine regularity. In total, 50% of participants experienced regular cycles for both the intervention and control cycle (n = 9), and 22% of participants (n = 4) experienced one regular and one irregular cycle.

The average overall adherence rate for completing the daily yoga protocol for one full MC was 77%. The range for daily intervention protocol compliance was from 33% to 100%. Two participants out of 18 (11%) completed the protocol on all days of their MC.

Participants in this sample had an advanced level of resistance training experience with 13 participants training at a competitive level. The participant's experience level in resistance training ranged from 6-11 years.

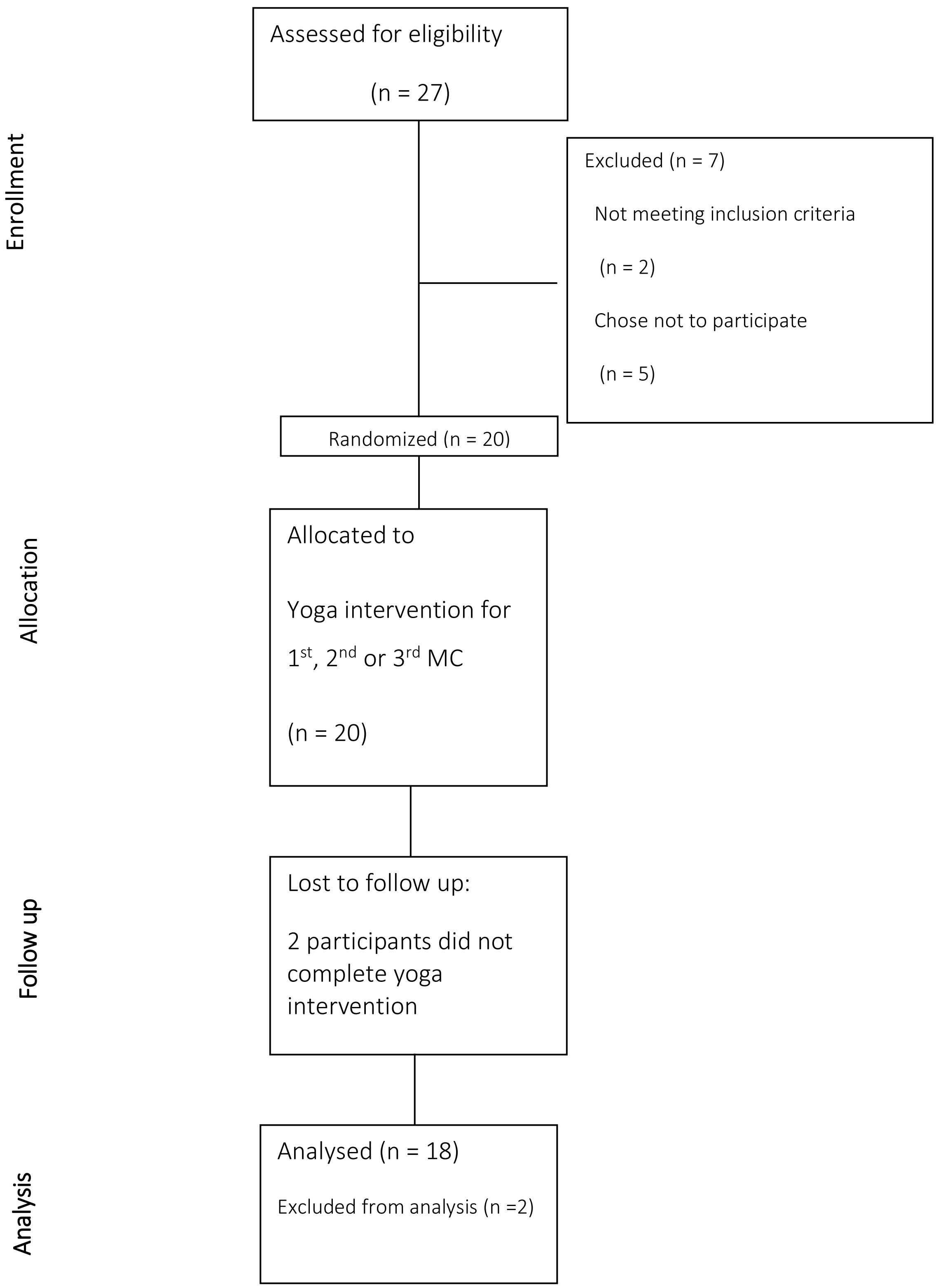


Figure 6-1 CONSORT Diagram

## Section 4.1: MC symptoms

There was a statistically significant Day*Cycle interaction for bloating ($p < 0.001$), low back pain ($p < 0.001$), and menstrual cramps ($p = 0.008$), indicating that the probability of experiencing these symptoms across the MC was different between the intervention and control cycles (**Table 6-1**). The predicted probabilities shown in **Figure 6-2** suggest a general trend for these symptoms to be lower at the end of the intervention cycle compared to the control cycle.

Table 6-1 Results of the generalised linear mixed models for MC symptoms

| Outcome | Term | Coefficient[A] | SE | Chi² [B] | P[C] | ICC[D] | $R^{2}$ [E] |
|---|---|---|---|---|---|---|---|
| Bloating | Day | -0.65 | 0.05 | | | | |
| | $Day^2$ | 0.04 | <0.01 | 646.8 | <0.001 | | |
| | $Day^3$ | <0.01 | <0.01 | | | | |
| | Cycle | -0.77 | 0.48 | 7.4 | 0.007 | 0.41 | 0.46 |
| | Day*Cycle | 0.19 | 0.08 | | | | |
| | $Day^2$*Cycle | -0.01 | <0.01 | 31.8 | <0.001 | | |
| | $Day^3$*Cycle | <0.01 | <0.01 | | | | |
| Headache | Day | -0.24 | 0.07 | | | | |
| | $Day^2$ | 0.02 | <0.01 | 69.9 | <0.001 | | |
| | $Day^3$ | <0.01 | <0.01 | | | | |
| | Cycle | -1.00 | 0.68 | 0.1 | 0.711 | 0.54 | 0.55 |
| | Day*Cycle | 0.07 | 0.11 | | | | |
| | $Day^2$*Cycle | <0.01 | <0.01 | 4.5 | 0.217 | | |
| | $Day^3$*Cycle | <0.01 | <0.01 | | | | |
| Low back pain | Day | -0.11 | 0.06 | | | | |
| | $Day^2$ | <0.01 | <0.01 | 31.3 | <0.001 | | |
| | $Day^3$ | <0.01 | <0.01 | | | | |
| | Cycle | 1.65 | 0.56 | 0.3 | 0.560 | 0.45 | 0.47 |
| | Day*Cycle | -0.43 | 0.09 | | | | |
| | $Day^2$*Cycle | 0.02 | <0.01 | 95.9 | <0.001 | | |
| | $Day^3$*Cycle | <0.01 | <0.01 | | | | |
| Menstrual cramps | Day | -1.10 | 0.18 | | | | |
| | $Day^2$ | 0.06 | 0.01 | 133.4 | <0.001 | | |
| | $Day^3$ | <0.01 | <0.01 | | | | |
| | Cycle | 2.94 | 0.86 | 9.3 | 0.002 | 0.29 | 0.56 |
| | Day*Cycle | -0.85 | 0.31 | | | | |
| | $Day^2$*Cycle | 0.07 | 0.02 | 11.8 | 0.008 | | |
| | $Day^3$*Cycle | <0.01 | <0.01 | | | | |

A: Coefficient presented as log-odds B: Type II Wald Chi-Squared statistic C: P value from Type II Wald Chi-Squared test D: Adjusted ICC, variance explained by the random effect (participant). E: Conditional $R^2$ (variance explained by fixed and random effects). This table shows the results as numerical values and the figures corresponding to the values are shown below.

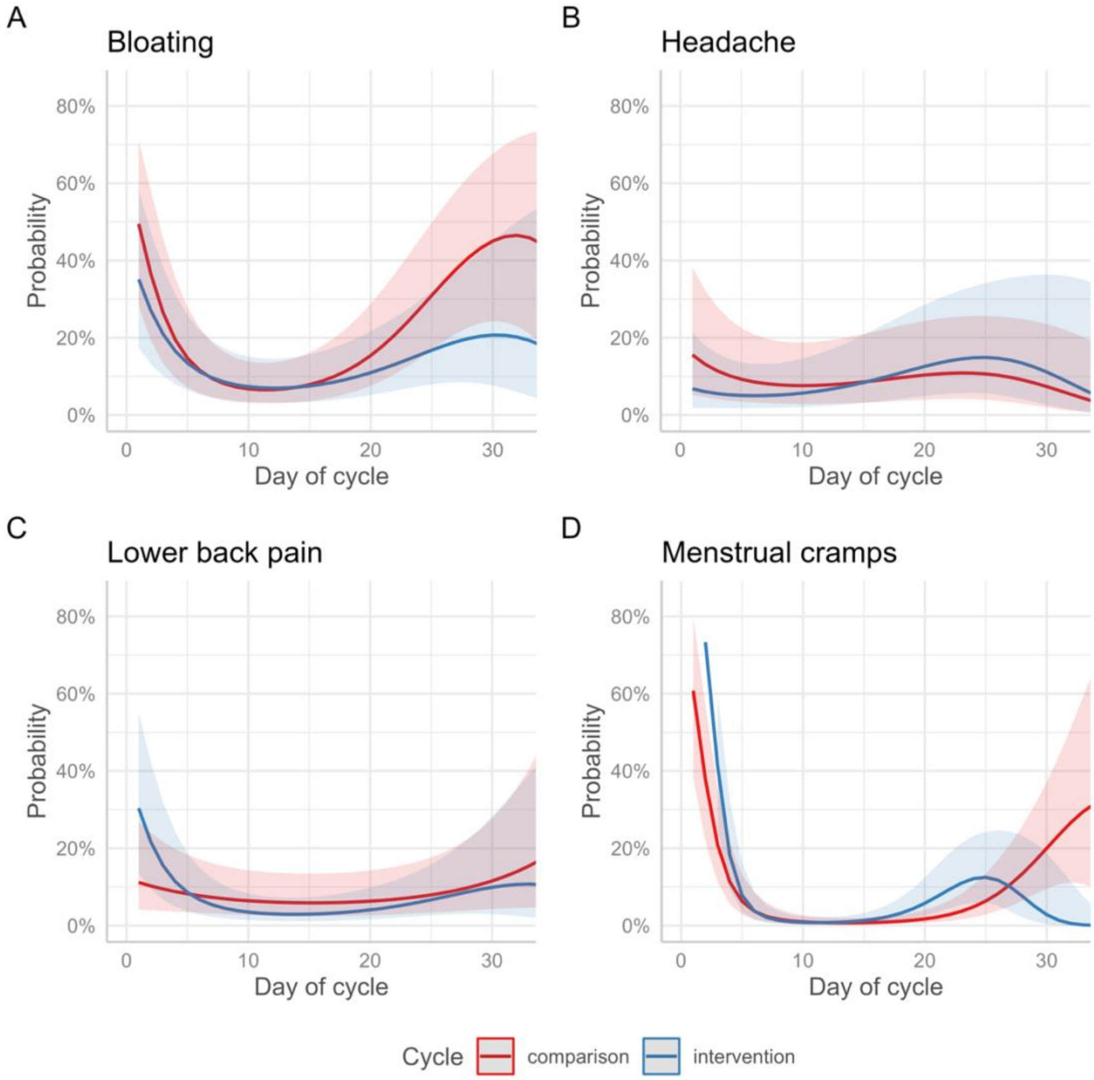


Figure 6-2 MC symptom predicted probability graphs.

*Predicted probabilities of experiencing MC symptoms across the cycle in the intervention compared to the control cycle.*

Legend: Figures 6-2 and 6-3 show the model-estimated means, represented as predicted probabilities (solid line) with 95% confidence intervals (shaded ribbon). These estimates were obtained from linear mixed models, with a binomial distribution and logit link function. The red lines represent the control cycle, and the blue line represents the intervention cycle.

## Section 4.2: Well-being measures

The probability of experiencing stress was significant in the Day*Cycle interaction ($p < 0.001$), with a lower probability of stress at the end of the intervention cycle than in the control cycle. The ICC for stress was higher than other measures (0.67), indicating that the results for stress are highly dependent on the participant, with low stress clustered within one participant, and high stress clustered in another participant, compared to other measures that were spread move evenly among participants. There were no significant associations for poor sleep quality or poor mood scores across the MC in the intervention compared to the control cycle. See **Figure 6-3** for associated graphs and **Table 6-2** for full results.

Table 6-2 Results of the generalised linear mixed models for measures of well-being

| Outcome | Term | Coefficient[A] | SE | Chi2 [B] | P[C] | ICC[D] | $R^{2}$ [E] |
|---|---|---|---|---|---|---|---|
| | Day | -0.51 | 0.23 | | | | |
| | $Day^2$ | 0.03 | 0.02 | 22.7 | <0.01 | | |
| | $Day^3$ | <0.01 | <0.01 | | | | |
| Mood | Cycle | 0.77 | 0.99 | 1.9 | 0.16 | 0.41 | 0.46 |
| | Day*Cycle | 0.04 | 0.30 | | | | |
| | $Day^2$*Cycle | -0.01 | 0.02 | 1.0 | 0.80 | | |
| | $Day^3$*Cycle | <0.01 | <0.01 | | | | |
| | Day | -0.29 | 0.15 | | | | |
| | $Day^2$ | 0.02 | <0.01 | 9.5 | 0.02 | | |
| | $Day^3$ | <0.01 | <0.01 | | | | |
| Sleep Quality | Cycle | -0.73 | 0.86 | <0.01 | 0.98 | 0.54 | 0.55 |
| | Day*Cycle | 0.20 | 0.23 | | | | |
| | $Day^2$*Cycle | -0.01 | 0.02 | 1.5 | 0.69 | | |
| | $Day^3$*Cycle | <0.01 | <0.01 | | | | |
| | Day | -0.13 | 0.06 | | | | |
| | $Day^2$ | <0.01 | <0.01 | 13.9 | <0.01 | | |
| | $Day^3$ | <0.01 | <0.01 | | | | |
| Stress | Cycle | 0.74 | 0.54 | 4.6 | 0.03 | 0.45 | 0.47 |
| | Day*Cycle | -0.25 | 0.08 | | | | |
| | $Day^2$*Cycle | 0.02 | <0.01 | 215.1 | <0.01 | | |
| | $Day^3$*Cycle | <0.01 | <0.01 | | | | |

A: Coefficient presented as log-odds B: Type II Wald Chi-Squared statistic C: P value from Type II Wald Chi-Squared test D: Adjusted ICC, variance explained by the random effect (participant). E: Conditional $R^2$ (variance explained by fixed and random effects). This table shows the results as numerical values and the figures corresponding to the values are shown below.

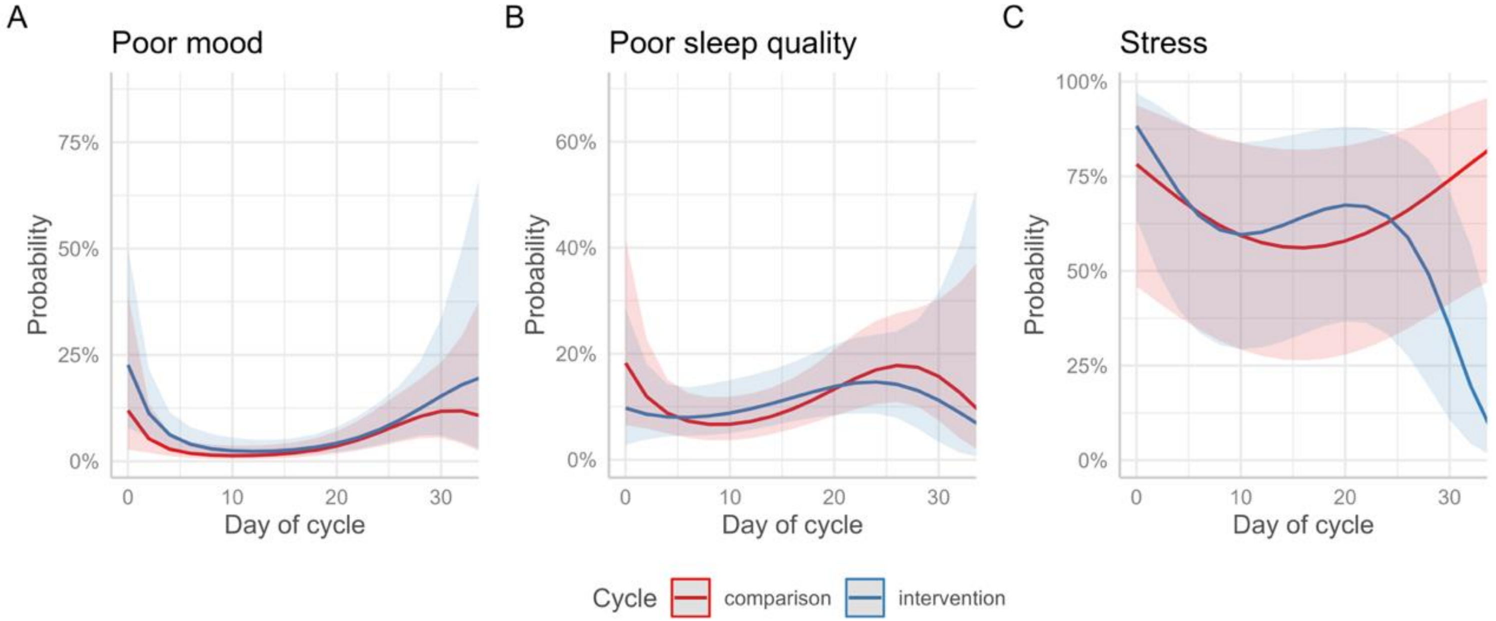


Figure 6-3 Measures of well-being predicted probability graphs

*Predicted probabilities of poor measures of well-being across the cycle in the intervention compared to the control cycle.*

## Section 4.3: Training

There was a statistically significant Day*Cycle interaction for estimated 1RM ($p = 0.004$) and sRPE ($p = 0.024$), both of which showed a more constant trend across the intervention cycle compared to the control cycle. The ICC for estimated 1RM (0.89) was higher than sRPE, indicating that estimated 1RM was more participant specific than sRPE, which is likely due to individual differences in estimated 1RM ranges. See **Figure 6-4** for associated graphs and **Table 6-3** for full results.

Table 6-3 Results from the linear mixed models for performance metrics.

| Outcome | Term | Coefficient[A] | SE | $Chi^2$ [B] | P[C] | ICC[D] | $R^2$ [E] |
|---|---|---|---|---|---|---|---|
| sRPE | Day | 0.09 | 0.13 | | | | |
| | $Day^2$ | <0.01 | 0.01 | 2.9 | 0.396 | | |
| | $Day^3$ | <0.01 | <0.01 | | | | |
| | Cycle | 0.62 | 0.75 | 0.2 | 0.891 | 0.19 | 0.22 |
| | Day*Cycle | 0.04 | 0.19 | | | | |
| | $Day^2$*Cycle | -0.01 | 0.01 | 9.4 | 0.024 | | |
| | $Day^3$*Cycle | <0.01 | <0.01 | | | | |
| 1RM | Day | -2.10 | 1.23 | | | | |
| | $Day^2$ | 0.23 | 0.09 | 17.6 | 0.001 | | |
| | $Day^3$ | -0.01 | <0.01 | | | | |
| | Cycle | -9.19 | 7.42 | 2.4 | 0.118 | 0.89 | 0.89 |
| | Day*Cycle | 2.73 | 1.99 | | | | |
| | $Day^2$*Cycle | -0.28 | 0.15 | 13.4 | 0.004 | | |
| | $Day^3$*Cycle | <0.01 | <0.01 | | | | |

A: Coefficient presented as log-odds B: Type II Wald Chi-Squared statistic C: P value from Type II Wald Chi-Squared test D: Adjusted ICC, variance explained by the random effect (participant). E: Conditional $R^2$ (variance explained by fixed and random effects). This table shows the results as numerical values and the figures corresponding to the values are shown below.

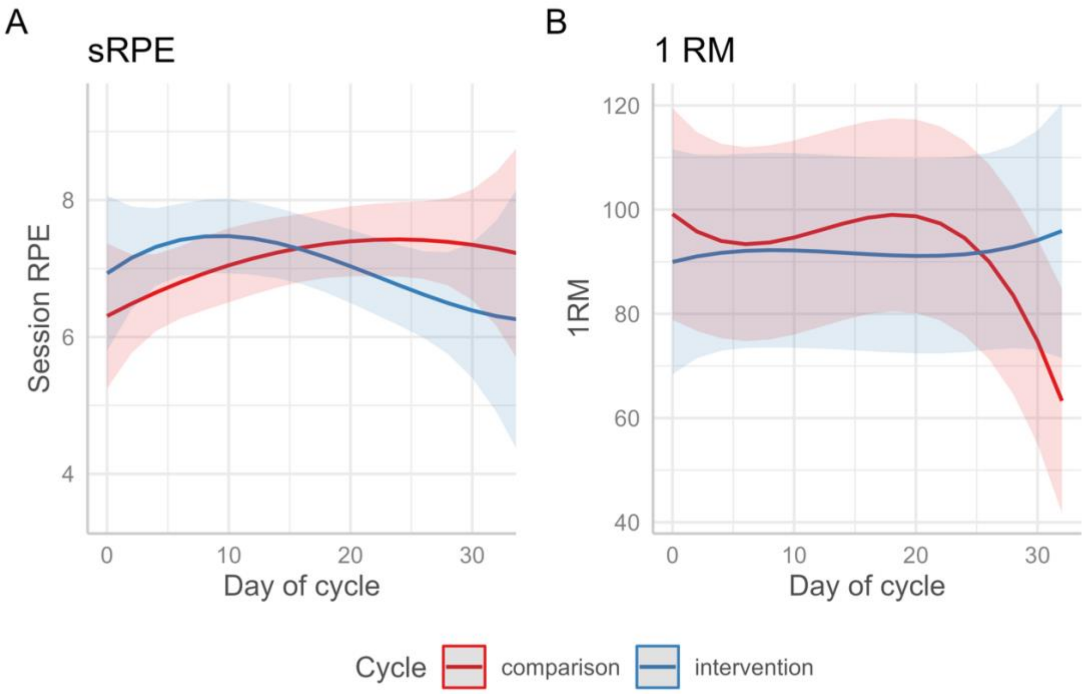


Figure 6-4 Perceived performance metrics graphs

*These graphs show the estimated means, obtained from linear models, of session RPE and estimated 1RM across the cycle in the intervention (blue) compared to the control cycle (red).*

## Section 5: Discussion

Our study found a significant association between the yoga intervention and the probability of experiencing MC symptoms, including bloating, cramps, and lower back pain. The probability of experiencing stress was also different between the intervention MC compared to the control MC, with a lower probability of stress during the intervention MC. Daily yoga also appears to be associated with changes in performance perceptions across the MC, as it seemed to have a stabilizing impact on estimated 1RM and sRPE during the intervention cycle, both of which trended down during the control cycle.

The findings from our study on yoga's association with changes in MC symptoms align with the literature review by Oates (2017), which reported on 15 studies that all concluded yoga reduced MC symptoms in some capacity. Our findings also align with a recent study that implemented a similar length yoga intervention and subsequently also found a significant reduction in menstrual cramps and related MC pain in the general population [38]. The concept of yoga interventions reducing stress and improving overall feelings of well-being is well supported by the existing literature on the general population [23,24,30,50,51], and our study further supports this notion by demonstrating similar results in an athletic population.

In contrast to previous literature on the general population, [30,38], our study did not show yoga participation to have a significant association with changes in sleep quality or mood. This difference in findings may be due to the intervention length or duration, participation adherence, or differences in question wording. Another factor to consider with this discrepancy in findings is that many other studies investigating yoga interventions are not only observing the specific impact of yoga but are simultaneously introducing physical activity generally to an otherwise sedentary population. While physical activity is linked to improved perceptions of physical health and fitness [52], these benefits may not be additive in already active individuals, such as the present study sample.

One distinctive feature of our study was the assessment of how yoga influenced perceptions of training during the MC in athletes and the potential for a mindful yoga practice to stabilize the MC's effects on athletes' performance perception. This finding is especially relevant since many surveys, qualitative studies, and literature reviews have cited that athletes report their performance being negatively impacted by their MC [5,7,53–55]. However, despite this negative perception, other literature reviews have concluded there is little effect from the MC phase on performance [56,57], which is potentially why a mindful practice that includes body awareness may negate some of these perceived MC performance effects. Overall, the findings of this study are comparable to the related existing literature on yoga's potential to reduce MC symptoms and encourage further development in its application for athletic women.

Since this is the first known study on the effect of a yoga intervention on MC symptoms and perceived performance in resistance training athletes, future confirmatory research, as well as research into other athletic populations is needed. This study has various strengths, primarily that it is novel and utilizes a short-duration yoga protocol that emphasizes a mind-body connection that can be applied in a variety of settings. While we investigated the utility of an at-home, video-delivered yin-style yoga intervention, since existing literature supports group-based classes and other intervention frequencies in the general population, future research should therefore apply these interventions to athletes.

## Section 5.1: Limitations

Since this study was undertaken during the COVID-19 pandemic, all procedures were completed from the participants' homes. Participants indicated in the app "yes" or "no" if they completed the protocol each day during their intervention cycle, but compliance with the protocol could not be confirmed. Participants were not screened for MC symptoms or cycle regularity prior to enrollment in the study, both factors may reduce or enhance the effects of the intervention and should be viewed as a limitation in application of these findings.

To minimize participant burden, we collected only a narrow set of information on MC symptoms and measures of well-being from participants. Collecting more detailed data in specific well-being categories may be useful to isolate the effects of the yoga intervention. All data collection for this study was conducted remotely, creating an increased chance for participant data entry errors and an inherent risk of self-reporting bias. Since this study was brief in duration for only one MC and with a limited sample size due to logistical constraints, the findings should be interpreted with caution and primarily used to inform future research rather than seen as conclusive evidence. Lastly, it should be noted that since it is impossible to blind participants to a yoga intervention there is an inherent chance of a placebo effect from this intervention style that may have influenced the results.

## Section 6: Conclusion

A 10-minute daily yoga practice is significantly associated with changes in MC symptoms and has the potential to mitigate some MC symptoms and stress perception in an athletic population. Furthermore, daily yoga was significantly associated with changes in perceived performance and may stabilize perceived performance metrics across the MC. Since most participants in this study had a reasonable level of compliance with the protocol, and previous literature has established the benefits and safety of yoga for athletes, further research on the use of yoga for MC symptom mitigation and perceived performance in athletes is warranted.

# Chapter 7 Discussion, future research directions, and practical applications

## Section 1: Summary and discussion

This thesis aimed to establish the MC characteristics and symptoms, as well as the perceived effects of the MC on performance in RT women. An additional aim was to investigate a potential method to alleviate MC symptoms in RT females. The second chapter literature review revealed the complexity of MC research in sports and the lack of consensus over the MCs potential effects on performance. Further, the literature review identified the lack of data on MC characteristics of the RT population and the need for interventions which can address problematic MC symptoms.

The first investigation (Chapter 3) was a survey of RT women to set the stage for further work by establishing perceived MC characteristics, MC symptoms, and potential MC effects on performance in RT women. Notably, most RT females shared similar MC characteristics as those reported in the general public. Most participants in this survey (68.3%) answered that their periods came regularly, with 72.7% reporting that their MC lasted 25-31 days. Competitive athletes were comparable, with most (68.1%) indicating that their periods came regularly and most (75.7%) reporting that their MC lasted 25-31 days. 92.0% of respondents to this survey reported experiencing MC symptoms, which is comparable to the existing literature examining other types of athletes [11,12]. Uterine cramps were the most common MC symptom (76.0%), and for some, symptoms could be very severe and limiting, which aligns with previous research [11,12]. 40.2% of participants indicated they used HCs, and the combined oral contraceptive pill was the most common form (43.8%). 45.0% of participants indicated they experienced some sort of HC side effect. Despite this large percentage of reported side effects from HC use, HC use was associated with a lower likelihood of experiencing MC symptoms overall, including cramps specifically. Most participants perceived their MC negatively impacted performance (59.4%), specifically during the late luteal phase or at the onset of the menstrual period, which also aligns with previous research [30,79]. Despite MC symptom severity being comparable, competitive athletes were less likely to alter workouts due to the MC and very unlikely (1%) to drop out of a competition due to the MC.

Because low energy availability is connected to MC regularity in conditions like RED-S [51,86], an exploratory survey on the diet practices, BID, EDs and MC characteristics in RT women was implemented (Chapter 4). Most participants (64.6%) reported they tracked calories, with a slightly higher percentage of competitive athletes (71.8%) tracking calories than recreational athletes. This prevalence of calorie tracking in competitive strength athletes is notably higher than previous research on the general population, which showed a prevalence of 12.3-26% [124,125]. In recreational-athletes, calorie restriction was primarily utilised for weight loss for aesthetic reasons (58.8%). Competitive athletes differed in their justification for calorie restriction, as fewer cited aesthetic reasons (35.7%), and more cited competition in a weight class-based sport (43.5%). 43.4% of participants reported experiencing BID “Often” or “All the time”, which is lower than the occurrence rates of 50-83% in mixed sports athletes [131]. Finally, a minority of participants (5%) had been diagnosed with an ED, which is lower than previous research on the prevalence of EDs in other athletes, which ranged from 18-42% [109,132,135]. An ED diagnosis was significantly associated with amenorrhea, aligning with previous research on RED-S and the Female Athlete Triad [51,86], which fits with the current model of understanding how low energy availability impacts MC hormone regularity. These results highlight the importance of screening for EDs and BID in strength and physique sports and monitoring the mental health of athletes.

Since surveys have inherent memory recall bias and it is challenging to determine MC characteristics without close hormonal monitoring [10,35], Chapter 5 aimed to establish the MC characteristics in a cohort of RT females as accurately as possible while monitoring changes in well-being and perceived performance. Most MC characteristics and symptoms in this RT cohort aligned with previous research in the general population; however, the frequency of irregular cycles was higher [138]. Noteworthy observation were the large amount of individual variation in total MC length, the number of days in which MC symptoms were experienced, and the variation in MC symptoms from cycle-to-cycle for a given individual. This high level of inter- and intra-individual variation may explain – at least in part – why the effects of the MC on sports performance are still unclear and why performance effects may be difficult to measure accurately. There was a significantly higher probability for general markers related to mental health to be lower during the beginning and end of the MC. Perceived performance metrics also changed across the MC, estimated 1RMs were lower towards the latter part of the MC, and PRS scores were lower at both the beginning and end of the MC. Conversely, session RPE did not show a significant association with MC day and stayed constant across the MC. Thus, session RPE may be a more consistent metric to determine the perceived difficulty of training sessions in athletic populations independent of the MC phase.

After establishing normative MC-related data among RT women, their perceptions of how MC symptoms impact their training and well-being (Chapters 2-4), and providing additional clarity and objectivity through monitoring a cohort of RT women (Chapter 5), Chapter 6 aimed to investigate the potential utility of a yoga mindfulness practice for MC symptom mitigation. This study was implemented as a small-scale study since it was both a novel concept in an athletic population and because sample size was logistically limited and in-person data collection was prevented by COVID-19 and the related government lockdowns. As demonstrated in a randomised crossover design, in a group of RT women, a short daily self-directed yoga intervention during one MC was associated with changes in MC symptoms. MC symptom occurrence was significantly lower in the intervention MC than in the control MC, and the probability of experiencing stress was lower as well. The yoga intervention also appeared to stabilise perceived performance metrics across the MC, with less variation in estimated 1RM and session RPE compared to the control MC.

## Section 2: Limitations

This thesis had several limitations due to COVID-19 lockdowns in New Zealand, which affected study design and data collection. Chapters 5 and 6 had to be re-designed for remote data collection due to the country's ever-changing landscape with lockdown levels. When stricter and longer-lasting lockdowns prevented gym access for participants in New Zealand, the need to recruit participants outside of the country arose. Although this enabled the study to move forward, it complicated certain aspects of the data collection, such as blood draws. Overall, the compliance for blood draws for Chapter 5 was much lower than anticipated due to closures, lockdowns, illness, and scheduling issues. This low compliance led to difficulty in utilising blood draws to confirm cycle regularity, as had been planned. COVID-19 also increased participant dropout rates as many contracted the illness or were close contacts of those who contracted it and had to isolate, preventing them from training. Thus, while remote collection allowed the study to be completed, it was with a smaller number of participants than initially anticipated.

## Section 3: Practical applications

Based on the findings in this thesis, the following recommendations can be made:

- MC effects on training should be treated with an individualised approach, as some women experience very severe and debilitating MC symptoms while others do not. The effects that the MC may have on performance are still unclear, but at this time, applying one MC-based programming style for all females is not supported by the existing literature.
- It is necessary to identify methods that can account for cycle variability and cycle irregularity to accurately isolate any performance effects related to the MC. There is a large amount of inter- and intra-individual variation in MC experiences, and the amount of variation from cycle-to-cycle for one individual can be high, with cycle length varying up to seven days and symptoms changing from cycle-to-cycle. This level of MC variation can be challenging to adjust for when measuring performance or training effects, as a symptom that may be severe one month may not be the following month. Further, irregular cycles are relatively common and should be considered and accounted for when evaluating the MCs impact on performance. Irregular cycles create a hormonal environment different from the regular MC, and accounting for their effects becomes more complex and nuanced as many females are unaware of their irregular cycles without hormonal monitoring.
- When evaluating MC effects, it is crucial to consider an individual's perception of their MC. The general perception among RT females is that certain MC phases or

MC symptoms decrease their performance capacity or strength. The psychological belief that specific phases of the MC can either enhance or hinder performance might have an independent impact, distinct from any actual hormonal effects, on training and performance. Thus, athletes' perceptions and beliefs should be considered when making coaching decisions.

- Changes in mental health status across the MC may be severe for some individuals and should be promptly addressed by coaches and athletes with proper treatment and care. Mental health metrics significantly change across the MC, and many RT females regularly endure changes in stress, mood, body image, and mood swings as part of the MC, which may affect training and performance. Therefore, coaches should develop appropriate rapport with their athletes to create an open environment where athletes feel comfortable discussing their MC experiences. Further, coaches should have access to appropriate mental health support staff for athletes that require such attention.
- It may be worthwhile for individuals struggling with MC symptoms and related performance concerns to consider incorporating a mindfulness yoga practice (or other similar mindfulness practices). Mindfulness yoga may reduce some MC symptoms and stabilise changes in perceived performance metrics across the MC. The effectiveness of this approach may vary depending on the symptoms of concern, likely resulting in a higher success rate for certain individuals compared to others.

## Section 4: Recommendations for future research

- Chapter 3 identified that over half of competitive strength athletes perceived that their MC negatively affected their performance during competition. Still, only 1% reported dropping out of a competition due to their MC. Additional research should explore how perceived MC effects impact performance, specifically how this differs between competitive and recreational athletes.

- Chapter 4 showed that calorie restriction is common among RT women; further research should investigate how periods of calorie restriction acutely affect MC symptoms and MC regularity and how this may differ among sports disciplines.
- The connection between mental health issues and the MC requires further exploration. Specifically, future research that uses validated questions to establish BID, EDs, anxiety, depression, and PMS prevalence in the RT population is needed. This research will not only help to clarify MC performance effects but may also enhance the quality of treatment for these conditions.
- Chapter 5 indicated that irregular cycles may be common among RT women. Without detailed hormonal monitoring, it is difficult to accurately categorise a cycle as regular or irregular. Any research investigating MC effects requires precise hormonal monitoring, preferably via blood draw. Thus, future research should ideally implement such blood-based monitoring, otherwise, it is difficult to attribute any performance effects to a given MC phase or its associated hormonal environment due to the likelihood of cycle irregularity.
- Chapter 5 also revealed how variable the MC is; more research is needed to better clarify the degree of inter- and intra-individual variation and the potential causes of these variations. MC variability may be a factor underlying the current challenge of identifying MC-related performance effects in the literature.
- Chapters 2, 3, and 5 established that MC symptoms are widespread in RT women and do not always respond to common first-line treatments. There is a

need for additional research to explore new options for mitigating MC symptoms, particularly among athletic populations.

- Chapter 6 demonstrated that mindfulness yoga may improve MC symptoms; additional research is needed to confirm this finding and provide additional context. Specifically, research that investigates different frequencies and types of yoga is warranted, in addition to other mindfulness practices. Furthermore, research that implements longer intervention periods and delves into the mechanisms responsible for these changes in MC symptoms is also needed.

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# Appendix A Ethics approval (Chapters 3 and 4)

AUT

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

## Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

5 March 2021

Eric Helms
Faculty of Health and Environmental Sciences

Dear Eric

Re Ethics Application: **21/22 Female Hormonal Cycle and Resistance Training**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

**Non-Standard Conditions of Approval**

1. Please remove the entire compensation paragraph from the Information Sheet.

Non-standard conditions must be completed before commencing your study. Non-standard conditions do not need to be submitted to or reviewed by AUTEC before commencing your study.

**Standard Conditions of Approval**

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
**Auckland University of Technology Ethics Committee**

Cc: kimsantabarbara@gmail.com; Nigel Harris

# Appendix B Ethics approval (Chapters 5 and 6)

**Auckland University of Technology Ethics Committee (AUTEC)**

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

17 June 2021

Eric Helms
Faculty of Health and Environmental Sciences

Dear Eric

Re Ethics Application: **21/22 Female Hormonal Cycle and Resistance Training**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 17 June 2024.

**Non-Standard Conditions of Approval**

1. Please send through a signed copy of the Data Sharing Agreement.

Non-standard conditions must be completed before commencing your study. Non-standard conditions do not need to review by AUTEC before commencing your study.

**Standard Conditions of Approval**

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
**Auckland University of Technology Ethics Committee**

Cc: kimsantabarbara@gmail.com; Nigel Harris

# Appendix C Ethics amendment approval (Chapter 6)

## Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
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www.aut.ac.nz/researchethics

11 November 2021

Eric Helms
Faculty of Health and Environmental Sciences

Dear Eric

Re: Ethics Application: **21/22 Female Hormonal Cycle and Resistance Training**

Thank you for your responses to the conditions for the amendment to your ethics application.

The amendment to the data collection protocol has been approved.

**Standard Conditions of Approval.**

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.
8. AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted. When the research is undertaken outside New Zealand, you need to meet all ethical, legal, and locality obligations or requirements for those jurisdictions.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
**Auckland University of Technology Ethics Committee**

Cc: kimsantabarbara@gmail.com; Nigel Harris

## Appendix D Survey questions from Chapters 3 and 4

This is a URL to access the survey questions that were used for Chapters 3 and 4

https://aut.au1.qualtrics.com/jfe/form/SV_aaZ6MXocZGmAezk