Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

RIDING WITH FLOW: MENSTRUAL HEALTH IN WORLD CUP AND WORLD CHAMPIONSHIP MOUNTAIN BIKERS.

A thesis submitted in partial fulfilment of the
requirements for the degree of

Master of Science
in
Exercise and Sport Science

at Massey University, Wellington,
New Zealand.

Mary-Ann Rongo Moller

2022

Abstract

Background: Menstrual health is an indicator of overall health and is an important aspect of female athlete physiology. Menstrual disturbances can have long term health consequences and are most likely related to high training volumes, disordered eating, and low energy availability. While menstrual health has been studied in some sports, it has been neglected in mountain biking.

Objective: To report the menstrual health status of female World Cup and World Championship Mountain bikers with a specific focus on 1) the prevalence of menstrual disturbances; 2) hormonal contraceptive use; and 3) menstrual cycle symptomology and period characteristics. A secondary aim of this research was to compare the menstrual health of cross-country riders and downhill riders.

Methods: An online survey was made available for female mountain bikers competing in the 2021 season of the UCI Mountain Bike World Cup Series, World Championships and Tokyo Olympics. There were a total of 76 valid survey responses.

Results: Riders were 85.5% (*n* = 65) cross-country riders and 14.5% downhill riders (*n* = 11). The prevalence of menstrual disturbances was 58% (*n* = 44), with 34% of riders reporting amenorrhea (*n* = 26) and 47% oligomenorrhea (*n* = 36). There were no significant age or discipline differences in menstrual disturbances. Twenty-five percent of riders (*n* = 19) were current hormonal contraceptive users. About a third of riders (29%, *n* = 22) experienced heavy menstrual bleeding. Fifteen percent of riders (*n* = 11) had been diagnosed with eating disorders, 58% (*n* = 44) engaged in disordered eating practices and 9% (*n* = 7) had been diagnosed with Relative Energy Deficiency in Sport (RED-S).

Conclusions: Over half of all riders in this study had experienced menstrual disturbances. Negative menstrual cycle symptoms were experienced by most. There were no significant differences in menstrual health when comparing cross-country and downhill riders. Eating disorders and associated behaviours were relatively high in mountain bikers and in the higher level riders this was only seen in cross-country riders. Male coaches were a barrier to communication around the menstrual cycle for some female athletes.

Acknowledgements

First and foremost, I would like to acknowledge and thank my supervisors Dr Paul Macdermid and Associate Professor Toby Mundel for their guidance throughout this process. I would also like to express my gratitude to Dr Glenn Brown for his invaluable expertise and assistance, particularly with my statistics, editing and reviewing. I'd like to also acknowledge all the female participants that took part in this research. I appreciate them taking the time out of their schedules to complete my survey and answering questions that are of quite a personal nature.

Lastly, this would not have been possible without the unwavering support and encouragement of my husband Paul. It is difficult to put into words how much I appreciate him, so I will just say thank you. This thesis is dedicated to my boys Braxton and Gordon. When they are old enough to understand the work that has gone into this, I hope they will be proud of their Mum.

Table of Contents

Abstract……ii

Acknowledgements……………………………………………………………………………………………………iv

Table of Contents………………………………………………………………………………………………………v

List of Figures……viii

List of Tables………x

List of Abbreviations…………………………………………………………………………………………………xi

Chapter 1: Introduction……………………………………………………………………………………………1

1.1 Background……1

1.2 Context……7

1.3 Purpose……7

1.4 Significance, scope, and definitions...8

1.5 Thesis outline...10

Chapter 2: Literature Review...11

2.1 Mountain biking: The sport..11

2.1.1 Downhill...11

2.1.2 Cross-country...12

2.2 Menstrual disturbances..13

2.2.1 Low energy availability, the female athlete triad and RED-S......................................16

2.3 Hormonal contraceptive use...19

2.4 Menstrual cycle characteristics...21

2.5 Summary and research questions...23

Chapter 3: Research Design...25

3.1 Methodology and research design..25

3.2 Participants...25

3.3 Survey design...27

3.4 Procedure and timeline..29

3.5 Ethics..30

3.6 Analysis...31

3.6.1 Exporting of data..31

3.6.2 Data preparation...33

3.6.3 Data analysis and statistical analysis...33

Chapter 4: Results...37

4.1 Participant characteristics...37

4.2 Menstrual disturbances and general health..40

4.3 Hormonal contraceptive use..46

4.4 Menstrual cycle characteristics...48

4.5 Cross-country versus downhill...55

Chapter 5: Discussion..61

5.1 Menstrual disturbances and general health..61

5.1.1 Menstrual disturbances..61

5.1.2 RED-S and the female athlete triad...63

5.1.3 Eating disorders...64

5.1.4 Concussion and depression..65

5.1.5 Iron deficiency and anaemia..67

5.2 Hormonal contraceptive use..68

5.2.1 Side effects....68

5.2.2 Types of hormonal contraception....70

5.3 Menstrual cycle characteristics....71

5.3.1 Symptoms and characteristics....71

5.3.2 Tracking the cycle and barriers to communication....74

5.4 Cross-country versus downhill....75

Chapter 6: Conclusions....79

6.1 Conclusions....79

6.2 Limitations....81

6.3 Recommendations....83

References....85

Appendices....91

Appendix A Survey....91

Appendix B Supplementary table 1....113

List of Figures

Figure 1: *A basic overview of the hypothalamic-pituitary-ovarian axis*.........................3

Figure 2: *Image to be used for social media sharing and advertising of the survey*.........30

Figure 3: *Combining of variables to create a new variable: menstrual disturbances*.......34

Figure 4: *Percent of riders at each level*..38

Figure 5: *Percent of riders in each mountain bike discipline*..38

Figure 6: *Riders by competition age – time spent competing at World Cup and World Championship level*..39

Figure 7: *Weekly training volume (hours), in competition phase and out of competition phase*..40

Figure 8: *Prevalence of present or historical menstrual disturbances by discipline*..........42

Figure 9: *Prevalence of present or historical menstrual disturbances by weekly training volume (hours) in competition phase*..42

Figure 10: *Prevalence of present or historical menstrual disturbances by weekly training volume (hours) out of competition phase*..43

Figure 11: *A comparison of weekly training volume (hours) between World Class DH and World Class XCO, out of competition phase*...56

Figure 12: *A comparison of weekly training volume (hours) between World Class DH and World Class XCO, in competition phase*...56

Figure 13: *A comparison of present and historical menstrual disturbances between World Class DH and World Class XCO*..57

Figure 14: *A comparison of present and historical diagnosed illnesses and injuries in World Class DH and World Class XCO*..58

Figure 15: *A comparison of the prevalence of heavy menstrual bleeding between World Class DH and World Class XCO*......59

Figure 16: *A comparison of the average number of menstrual cycle symptoms experienced between World Class DH and World Class XCO*......60

Figure 17: *Prevalence of riders that missed or modified their training in the last six months due to menstrual cycle symptoms. A comparison between World Class DH and World Class XCO*......60

List of Tables

Table 1: *Categories of survey questions based on themes and examples of questions in each*....................32

Table 2: *Present and historical menstrual disturbances*....................41

Table 3: *Prevalence of clinically diagnosed illnesses and injuries*....................45

Table 4: *Prevalence of disordered eating practices*....................46

Table 5: *Prevalence of hormonal contraceptive use, type and reason for use*....................47

Table 6: *Prevalence of hormonal contraceptive side effects*....................48

Table 7: *Menstrual cycle characteristics*....................50

Table 8: *The menstrual cycle in relation to training and racing*....................52

Table 9: *Prevalence of riders who track their menstrual cycle and method used*....................54

Table 10: *Communication with support staff about the menstrual cycle, including whether or not they talk with their coach, experience barriers and what these perceived barriers are*....................54

Table A1: *Statistical tests and results*....................113

List of Abbreviations

RED-S: Relative energy deficiency in sport

XCO: Cross-country or cross-country Olympic format

DH: Downhill

U23: Under 23 years old, age category includes riders aged 19-22 years old.

U23/Elite: Combined category, for analysis, of riders racing in U23 or elite grades.

World Class XCO: Cross-country riders in this study who are racing at an elite or under 23 level, who have also placed in the top 10 in a World Cup or World Championship race in the two years prior to taking this survey.

World Class DH: Downhill riders in this study who are racing at an elite or under 23 level, who have also placed in the top 10 in a World Cup or World Championship race in the two years prior to taking this survey.

IUD/s: Intrauterine device/s

COCP: Combined oral contraceptive pill

MD: Menstrual disturbances

DE: Disordered eating

LBD: Low bone density

HC: Hormonal contraception

MC: Menstrual cycle

GnRH: Gonadotropin releasing hormone

FSH: Follicle stimulating hormone

LH: Luteinising hormone

Chapter 1. Introduction

This chapter outlines the background (section **1.1**) and context (section **1.2**) of this research, and its purpose (section **1.3**). Section **1.4** describes the significance and scope of this research and outlines any definitions used. Lastly, section **1.5** provides an overview of the remaining chapters in this thesis.

1.1. BACKGROUND

Despite huge growth in women's sport, performance-based research on elite female athletes is still lacking (Bruinvels et al., 2017; Elliott-Sale et al., 2021; McNulty et al., 2020). A recent review by Elliott-Sale et al. (2021) highlight that researchers have avoided using female participants with only 4 to 13% of journal articles in sports and exercise science including only female participants. It is assumed that women are excluded due to the additional time and cost involved due to the requirement of repeated measures across the menstrual cycle in order to account for the potential confounding effect of hormone fluctuations (Elliott-Sale et al., 2021). Due to the small quantity of research, this has limited knowledge and understanding of ovarian steroids on athletic performance (Elliott-Sale et al., 2021). When it comes to sex-specific research and guidelines, the effects of the menstrual cycle and an athlete's menstrual health is a part of a woman's physiology that cannot be overlooked, especially with the rising number of women in elite sport. Understanding the ovarian steroid hormones and the effects on performance and body systems also provides an opportunity for the marginal gains required for success at an elite level (Elliott-Sale et al., 2021). There is still a lack of knowledge and understanding among athletes, coaches and support staff on menstrual health (Bruinvels et al., 2017). Further, it has been shown that male coaches

struggle to have conversations with their female athletes on this topic (Brown, Knight, & Forrest, 2021) and unfortunately a loss of menstruation, which is common among the most active female athletes, has been somewhat normalised in elite sport (Tan, Calitri, Bloodworth, & McNamee, 2016) and even seen as a sign of peak performance. These factors are barriers to supporting the health and wellbeing of female athletes, which is essential for peak performance and longevity in sport.

The menstrual cycle is an important biological process that is characterised by large cyclic fluctuations in endogenous hormones, mainly estrogen and progesterone (McNulty et al., 2020). The physiology underlying a healthy menstrual cycle is a complex interaction between neural, endocrine and cellular factors involving the hypothalamus in the brain, the front lobe of the pituitary gland called the anterior pituitary, the ovaries and uterus (Hawkins & Matzuk, 2008; Williams, Etter, & Lieberman, 2017). **Figure 1** gives a general overview of the main regulatory factors involved in the menstrual cycle and the interactions at play, referred to as the hypothalamic-pituitary-ovarian axis. Regulation begins in the hypothalamus which secretes gonadotropin releasing hormone (GnRH) to stimulate the anterior pituitary gland to release both follicle stimulating hormone (FSH) and luteinising hormone (LH). Follicle stimulating hormone and luteinising hormone stimulate the ovaries to produce the ovarian steroid hormones estrogen and progesterone. These then act on the endometrium (lining of the uterus) and feedback to stimulate the hypothalamus and anterior pituitary (Hawkins & Matzuk, 2008).

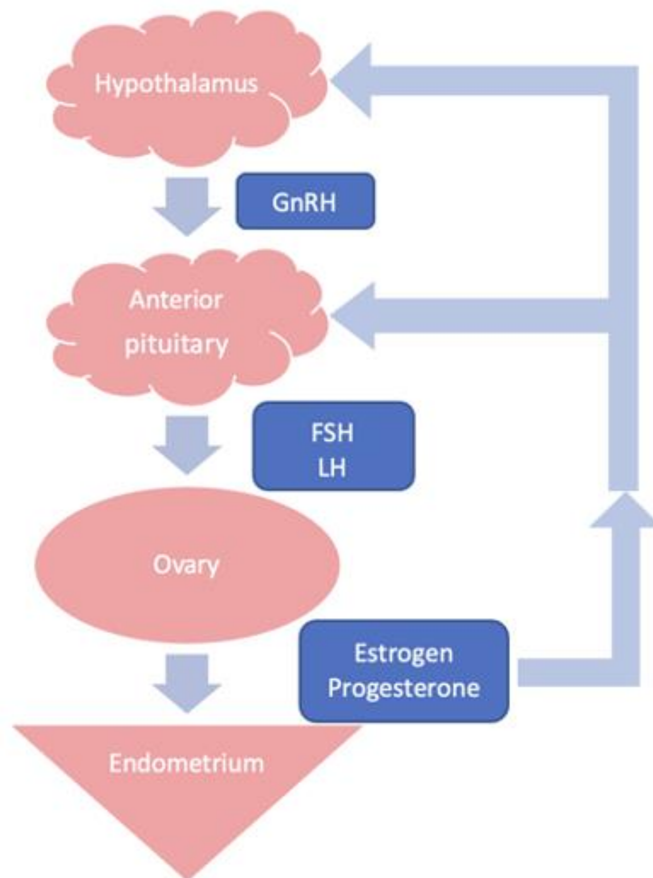

Figure 1. *A basic overview of the hypothalamic-pituitary-ovarian axis.*

Eumenorrhea describes a healthy menstrual cycle of approximately 28 days, however this can vary widely from 21 to 34 days (Elliott-Sale et al., 2021). Menarche is the first menstrual bleed a young woman experiences, usually around the age of 13 years old (Canelón & Boland, 2020). Delayed menarche or primary amenorrhea is the absence of a period after the age of 15 years old. Secondary amenorrhea occurs when there is an absence of a period for at least three months, following menarche. Both primary and secondary amenorrhea represent the most severe type of menstrual disturbance where there is complete suppression of reproductive axis activity (i.e., functional hypothalamic amenorrhea)(Williams et al., 2017). Oligomenorrhea describes irregular periods with cycle lengths ranging from 36 to 90 days. The menstrual cycle's status sits along a continuum from amenorrhea to

eumenorrhea. Presentation of menstrual disturbances, such as irregular periods or a loss of periods, is evidence of the hypothalamic-pituitary-ovarian axis adaptation to stressors such as high psychological stress or low energy availability (Prior, 2022). Low energy availability in athletes is most often related to excessive exercise, disordered eating, or a combination of both which may lead to a woman's body being no longer able to sustain basic biological functions, such as reproduction (Huhmann, 2020; Melin et al., 2014; Shufelt, Torbati, & Dutra, 2017).

Optimal menstrual health is dependent on the right balance of both estrogen and progesterone at different phases throughout the menstrual cycle (Prior, 2022). Based on a 28-day cycle, the menstrual cycle can be divided up roughly into two phases, phase 1) the follicular phase or low hormone phase and phase 2) the luteal phase or high hormone phase (Reed & Carr, 2015). Phase 1) begins with menstruation on day one, which can last anywhere from three to seven days. The follicular phase is characterised by the ripening of the follicles preparing the egg for release from the ovary and into the fallopian tube. Estrogen, progesterone, luteinising hormone, and follicle stimulating hormone are all low. During this phase, serum estrogen levels rise in parallel to the growing follicle (Reed & Carr, 2015). Day 12 sees a surge in estrogen which needs to be >200 pg/mL for 50 hours in order for ovulation to occur (Reed & Carr, 2015). Ovulation occurs around day 14 in the presence of a surge of follicle stimulating hormone and luteinising hormone. This is the end of phase 1) and the beginning of phase 2) which goes from day 14 to day 28. The luteal phase is characterised by the ripening of the corpus luteum. During this phase, estrogen and progesterone rise to a peak in preparation of implantation of the egg into the uterus (Reed & Carr, 2015). If implantation does not occur, estrogen and progesterone levels drop and the shedding of the

lining of the uterus occurs, which is day one of the women's period and the start of a new cycle (Williams et al., 2017).

Adaptation of the hypothalamic-pituitary-ovarian axis, because of physiological stressors, may contribute to a hypo-sex hormone environment (Prior, 2022). This appears to occur as a *graded response* with the preservation of estrogen being prioritised over progesterone. High levels of progesterone during the luteal phase raises the core temperature and requires approximately 300 kilocalories of increased energy (Prior, 2022). Therefore, to maintain energy balance, progesterone levels drop. This often results in subclinical menstrual disturbances such as anovulation or short luteal phase defects (Maruo, Katayama, Barnea, & Mochizuki, 1992). In the case of the more severe amenorrhea and oligomenorrhea both estrogen and progesterone are low. This process of reproductive suppression is adaptive for maintaining the energy balance of the female.

Low estrogen and progesterone can have both profound and possibly irreversible effects on many systems in the body including bone metabolism, cardiovascular system, reproductive system, and psychological health (Huhmann, 2020; Shufelt et al., 2017). Low estrogen can result in increased osteoclast activity (breaking down of bone), the suppression of bone production due to osteoblast apoptosis, increased cortisol, decreased calcium absorption from the intestines and hypothyroidism (Shufelt et al., 2017). These factors can lead to low bone density, increased injuries such as stress fractures and early onset osteoporosis (Huhmann, 2020; Melin et al., 2014). There is also increasing research on subclinical menstrual disturbances, in which progesterone is low but estrogen is sufficient, being associated with a loss of bone mineral density (Prior, 2022). Estrogen is a strong vasodilator and low estrogen can result in impaired vasodilation of endothelium-dependent muscles (De Souza & Williams, 2004; Redman & Loucks, 2005; Shufelt et al., 2017). This may

increase the risk of developing premature cardiovascular disease (De Souza & Williams, 2004; Redman & Loucks, 2005; Shufelt et al., 2017). In addition, estrogen acts on many parts of the brain and regulates neurotransmitters such as serotonin and dopamine (Shufelt et al., 2017). Consequently, low estrogen is associated with mood disturbance and females presenting with functional hypothalamic amenorrhea have been found to be more susceptible to anxiety and depressive traits (Shufelt et al., 2017). Adaptation of the hypothalamic-pituitary-ovarian axis and resulting hypo-sex hormone environment is likely to lead to infertility (Brown, 2011).

Menstrual disturbances are an early sign of low progesterone or estrogen and can provide clues to health problems that go beyond reproduction (Williams et al., 2017). In an athlete with menstrual disturbances, normal biological processes are beginning to shut down and long-term health consequences may result. Not to mention, the foundations of good health must be laid to sustain training and reach peak performance. The menstrual cycle is therefore an incredibly important marker of health for female athletes and irregularities related to psychological stress, training load, nutritional intake, or sleep, require further investigation.

Based on what is known from research in other sports, athletes that are training and competing at an elite level are at increased risk of menstrual disturbances and associated negative health consequences (Goodwin et al., 2014; Meng et al., 2020). Further, the menstrual cycle and the changes in hormone levels can have a range of different effects on female athlete physiological systems including cardiovascular, respiratory, metabolic and neuromuscular parameters (McNulty et al., 2020). Mountain biking is a highly competitive, professional sport which has multiple disciplines including cross-country and downhill. While the physiological demands of this sport have been well documented (Berry, Koves, & Benedetto, 2000; Chidley, MacGregor, Martin, Arthur, & Macdonald, 2015; Gregory, Johns, &

Walls, 2007; Hurst & Atkins, 2006; Impellizzeri & Marcora, 2007; Novak, Bennett, Fransen, & Dascombe, 2018; Sperlich et al., 2012), very few of these studies included female participants. There is currently no sex-specific research on women in this sport, so the menstrual health of female mountain bikers is unknown.

1.2. CONTEXT

Elite female mountain bikers competing at World Cup and World Championships level train and compete at the highest level while also managing the individual responses to the well-established and predictable changes in endogenous hormones across the menstrual cycle. Unfortunately, there is no research to date on the menstrual health of elite female mountain bikers, despite this being a sport where athletes are at risk of low energy availability and the associated disruption to healthy menstruation and other health consequences. These women are likely to be at increased risk of low energy availability due to the high training loads required to compete at such a high level and increased focus on being lean for improved performance. These risk factors are even more relevant to cross-country riders who race in a longer duration endurance event and would have some benefits with having a lower body weight for the uphill parts of the race. Due to the differences in disciplines, it would not be expected that downhill riders would have the same risk of being in an energy deficient state as cross-country riders.

1.3. PURPOSE

The aim of this study was to report the menstrual health status of female World Cup and World Championship Mountain bikers, with a specific focus on:

- The prevalence of menstrual disturbances

- Hormonal contraceptive use
- Menstrual cycle symptomology and period characteristics

The secondary aim of this study was to compare the menstrual health status of these riders by discipline, cross-country and downhill.

1.4. SIGNIFICANCE, SCOPE, AND DEFINITIONS

This research was needed to fill the gap in the knowledge of menstrual health in elite female mountain bikers. This was a novel contribution to the research on this sport. This also contributed, in a wider sense, towards closing the gender gap for women in sport and exercise science research and to guide future directions of research. It is crucial that the long-term health of female athletes is prioritised, and research focussed on sex-specific health issues is needed. It is hoped that this research helps to normalise conversations on the menstrual cycle and hormonal contraceptive use and helps to shift the thinking around periods being a "problem" to instead being a part of what makes an athlete healthy and able to perform at her best. Insights and findings from this research may benefit female mountain bikers at both an elite and non-elite level, coaches, support staff and parents, female athletes in other sports, the wider sporting community, and the scientific community.

To maintain a homogenous group, the target population was limited to only athletes competing at the highest level in this sport: World Cups, World Championships, and the Olympics. Comparing data to females at lower levels in this sport would have been interesting but was beyond the scope of this research. Due to the survey method used, this research was limited to self-reported data and perceived impacts and experiences. Measured variables and conclusions on causation were not possible.

Menstrual disturbances in this study refer only to amenorrhea and oligomenorrhea. Unless stated otherwise, amenorrhea includes primary (no period after the onset of puberty) and/or secondary (loss of period). Although there are four main disciplines of cross-country mountain biking which include: cross-country short track (XCC), cross-country eliminator (XCE), cross-country marathon (XCM) and cross-country Olympic format (XCO), in this study the term “cross-country” will refer to only cross-country Olympic format (XCO).

According to the Participant Classification Framework provided by McKay et al. (2022) all participants in this study were either Tier 4 Elite/International athletes or Tier 5 World Class. Some of the defining criteria of Tier 4 Elite/International athletes include maximal or near maximal training, competing at an international level and a top 4-300 world ranking (McKay et al., 2022). Tier 5 World Class athletes are Olympic or World medallists with a top 3-20 world ranking and/or a top 3-10 at an Olympics/World Championships (McKay et al., 2022). Regarding sport-specific terminology, “elite” is used for the category and race in which riders are aged 23 years and older. This is the most competitive age group and race in this sport. In this study, the under 23 riders and “elite” riders were combined for analysis of results into a group called “U23/Elite”. Further details on this grouping and terminology are in **Chapter 3.6.3. Data analysis and statistical analysis**. In relation to this study, the term “elite” is used to describe all athletes, unless otherwise stated, given all participants in this study are at Tier 4 Elite/International level or above. It can be difficult to conduct research on athletes at this level given their smaller numbers and lack of availability (McKay et al., 2022), therefore findings from this research provided particularly valuable insights as they relate to the high-performance sport setting.

1.5. THESIS OUTLINE

As an overview, the thesis chapters are as follows: **Chapter 2. Literature review** of the most recent research on menstrual health in elite athletes in other sports and some background on the physiological demands of mountain biking. The end of this chapter also includes research questions; **Chapter 3. Research design** includes methodology, participants, survey design, procedure, and timeline; **Chapter 4. Results** on menstrual disturbances and general health, hormonal contraceptive use, menstrual cycle characteristics and a comparison of cross-country and downhill; **Chapter 5. Discussion** of the most important findings as they relate to the research objectives, as well as other findings of interest; and finally, **Chapter 6. Conclusions** including limitations and recommendations of practical takeaway messages and future directions of research.

2. Literature Review

There is currently no published research specifically on menstrual health in female mountain bikers. Therefore, this review will summarise and discuss the most recent research on menstrual health in elite female athletes in other sports. Specific topics to be examined include: 1) a brief overview of the sport of mountain biking and the specific physiological demands of each discipline; 2) menstrual cycle disturbances and the association with low energy availability, the female athlete triad and Relative Energy Deficiency in Sport (RED-S); 3) hormonal contraceptive use; and 4) menstrual cycle characteristics.

2.1. MOUNTAIN BIKING: THE SPORT

Mountain biking is not only one of the most popular recreational outdoor activities worldwide but since its' first official competitions in the early 1980s it has gone on to grow as a highly competitive and professional sport (Impellizzeri & Marcora, 2007). Different disciplines emerged including downhill and cross-country. The first World Championships were organised by the Union Cycliste Internationale (UCI) in 1990 and the first World Cup Series followed in 1991. In 1996, cross-country mountain biking was included in the Atlanta Summer Olympic Games in the circuit racing format that is now called cross-country Olympic format (XCO). Although there are other types of cross-country racing, given this study only includes cross-country Olympic format this will just be referred to as cross-country or XCO in the abbreviated form.

2.1.1. Downhill

Downhill is a race against the clock, descending on a variety of fast and technical terrain designed to test the riders' technical skill and physical ability. Riders need to navigate

roots, rocks, jumps and other natural and man-made obstacles. Speeds in the women's races can reach up to 70km/h (UCI, 2022a). Race distance is a maximum of 3.5km with a finishing time of two to five minutes (UCI, 2022c).

A high aerobic and anaerobic capacity is required for downhill, although not as high as in cross-country (Sperlich et al., 2012). Sperlich et al. (2012) observed intensities of >90% of heart rate peak for 80% of entire race time in male downhill racers competing in the International German Downhill Championships. Even so, there are relatively low power outputs due to high speeds and more than half of race time spent not pedalling (Hurst & Atkins, 2006). Power output is intermittent and mostly determined by the race course. Heart rates remain high though, due to mental stress and the dynamic and isometric muscular contractions required for stabilising and bike handling (Hurst & Atkins, 2006). Skill development, self confidence and aerobic capacity, using full body muscle groups including the upper body and handgrip endurance, have been identified as important measures for performance in downhill (Chidley et al., 2015).

2.1.2. Cross-country

What differentiates cross-country from other mountain bike disciplines is the mass sprint start followed by the completion of a pre-determined number of laps of approximately 4-6km with a finishing time of 1hr 20min to 1hr 40min for the elite category. Finishing times for the Junior (under 19 years old) and Under 23 (19-22 years old) categories range from 1hr to 1hr 30min (UCI, 2022b). The duration of these events preclude cross-country as an endurance sport. Races are characterised by challenging climbs immediately followed by technical descents over varied terrain including roots, rocks, drops and other obstacles (UCI, 2022a). Due to the majority of time spent climbing with the rider needing to work against gravity, a low total mass for a high power to weight ratio has been highlighted throughout

the literature as important for performance in cross-country (Berry et al., 2000; Gregory et al., 2007; Impellizzeri & Marcora, 2007; Novak et al., 2018). Although there are a lot of similarities with endurance sports like running, Macdermid and Stannard (2012) suggest that the highly intermittent nature of cross-country makes it more comparable with high intensity team sports like soccer and basketball (with power surges, changes of direction and the erratic nature).

2.2. MENSTRUAL DISTURBANCES

Elite female athletes are known to be more susceptible to menstrual disturbances, often as a consequence of low energy availability associated with high training volumes and energy intake insufficient for energy expenditure. In this review, the term menstrual disturbances refers to oligomenorrhea and amenorrhea only, unless otherwise stated. One review has reported the prevalence of menstrual disturbances as 2% to 5% in the general population (Burrows & Bird, 2000), however, this is higher in more recent research (Goodwin et al., 2014; Kwak, Kim, & Baek, 2019). Data from a nationally representative survey in Korea showed 14% of women in the general population experienced menstrual disturbances (Kwak et al., 2019). A study examining the female athlete triad in elite endurance athletes recorded menstrual disturbances in 29% of non-athletic controls (Goodwin et al., 2014). Research on elite athletes has consistently reported a higher prevalence, ranging from 27% to 77% (Goodwin et al., 2014; Martin, Sale, Cooper, & Elliott-Sale, 2018; Melin et al., 2015; Meng et al., 2020; Oxfeldt, Dalgaard, Jørgensen, & Hansen, 2020; Pollock et al., 2010; Quah, Poh, Noor, & Ng, 2009).

Taking a closer look at specific types of menstrual disturbances, the prevalence of primary or secondary amenorrhea has been reported as high as 45% in Danish and Swedish

endurance athletes (Melin et al., 2015), 31% in Chinese athletes in aesthetic sports (Meng et al., 2020) and 25% in British endurance runners (Pollock et al., 2010). Yet, lower numbers have also been recorded: 4% in Norwegian endurance athletes (Solli, Sandbakk, Noordhof, Ihalainen, & Sandbakk, 2020), 9% in Australian team and individual sport athletes (Armour, Parry, Steel, & Smith, 2020) and 10% in American long-distance runners (Cobb et al., 2003). Similarly, the prevalence of oligomenorrhea is varied and ranges from 14% to 40% in elite athletes across a variety of sports (Armour et al., 2020; Cobb et al., 2003; Goodwin et al., 2014; Melin et al., 2015; Meng et al., 2020; Pollock et al., 2010; Quah et al., 2009; Solli et al., 2020).

Delayed menarche has been found to be a strong predictor of later menstrual disturbances (Cobb et al., 2003). Survey data from 140 elite Norwegian endurance athletes competing in cross-country skiing and biathlon suggest 15% experienced delayed menarche (Solli et al., 2020). Likewise, 22% reported delayed menarche in an online survey of 219 elite New Zealand athletes supported by High Performance Sport New Zealand (Heather et al., 2021) . However, much higher prevalence was seen in Kenyan long- and middle-distance runners, with 60% reporting delayed menarche, which was also significantly higher than 14% of non-athletes in the same study (Goodwin et al., 2014).

Menstrual disturbances are more common in endurance (e.g. distance running, cross-country skiing), aesthetic (e.g. dancing, figure skating, gymnastics) and weight class sports (e.g. martial arts, rowing) compared to power (e.g. sprinting, track cycling), technical (e.g. fencing, archery, shooting,) and ball game sports (e.g. hockey, squash, basketball) (Quah et al., 2009; Torstveit & Sundgot-Borgen, 2005b). This is due to endurance, aesthetic and weight class sports placing a greater emphasis on achieving a lower body weight, either for reasons of wanting to achieve a greater power to weight ratio, for “making weight” to compete in a

certain weight category or in sports where an athlete is judged partially on physical appearance. These “lean” sports often normalise extreme dietary and training practices, often leading to body dissatisfaction, eating disorders and low energy availability (Heather et al., 2021; Meng et al., 2020; Quah et al., 2009; Torstveit & Sundgot-Borgen, 2005b). To illustrate, a study of 186 elite Danish athletes reported more menstrual disturbances in endurance athletes than in power athletes, at 69% and 34% respectively (Oxfeldt et al., 2020). Further, Oxfeldt et al. (2020) found that amenorrhea was associated with higher cardiovascular training volume and a lower body mass index (BMI) in endurance athletes. These relationships were not present in technical or power athletes (Oxfeldt et al., 2020). This finding is supported by those of Cobb et al. (2003), in a study of collegiate and regional runners, stating that athletes with menstrual disturbances ran 18% more miles than eumenorrheic women. Further highlighting the impact of endurance training on menstruation, 30% of Swedish endurance athletes reported a loss of period with high training volumes and 20% had loss of menses with large amounts of high intensity training (Solli et al., 2020).

A major limitation in menstrual health research to date is the scarce data on subtle or sub-clinical menstrual disturbances such as luteal phase defects and anovulation, which are associated with decreased fertility and habitual abortions (De Souza, 2003; De Souza et al., 2010). De Souza et al. (2010) reported luteal phase defects in 27% of exercising women and anovulation in 25%. These rates were significantly higher than what was seen in sedentary women in the same study. Menstrual health research mostly relies on self-report methods which will only capture irregularities noticeable to the women themselves, such as cycle length (oligomenorrhea) or loss of period (amenorrhea)(De Souza et al., 2010). Daily hormone measures required to detect sub-clinical menstrual disturbances are expensive,

timely and often not practical. As a result, these types of menstrual disturbances are usually undiagnosed in women and underreported or not covered in the research (De Souza, 2003).

2.2.1. Low energy availability, the female athlete triad and RED-S

It is important to discuss the mechanisms that underpin menstrual disturbances and the associated syndromes. Low energy availability and menstrual disturbances are closely linked and this is well documented in the literature (Castanier et al., 2021; Cobb et al., 2003; De Souza et al., 2010; Melin et al., 2015; Meng et al., 2020; Mountjoy et al., 2014; Oxfeldt et al., 2020; Torstveit & Sundgot-Borgen, 2005a; Williams et al., 2017). Low energy availability is the energy deficit created when an athlete's energy intake does not match the amount of energy expended through exercise, resulting in inadequate energy for optimal health and performance (Mountjoy et al., 2018). This can present as menstrual disturbances which is essentially suppression of the reproductive system for energy conservation purposes. Goodwin et al. (2014) reported an alarmingly high 92% of Kenyan distance runners with low energy availability compared to 29% of non-athlete controls. Additionally, in a study of 40 endurance athletes in mostly triathlon and distance running, 63% had low or reduced energy availability (Melin et al., 2015). Interestingly, there was no relationship observed between energy availability and anthropometric measurements (i.e., non-invasive measurements of the body such as body weight, circumference measurements or BMI), however, a trend was observed between higher weekly training hours and reduced energy availability (Melin et al., 2015). A study of 166 Chinese athletes in aesthetic sports reported that 56% of elite athletes were considered to be at significantly increased risk of low energy availability versus 35% of recreational athletes (Meng et al., 2020). Moreover, elite athletes had significantly higher training volumes than recreational athletes (Meng et al., 2020), which supports findings from Melin et al. (2015).

The relationship between low energy availability and menstrual disturbances is so commonly seen in sport that the following syndromes were created to better describe how these factors are interrelated: The female athlete triad and RED-S (Mountjoy et al., 2018). Low energy availability is an aetiology of both RED-S and the female athlete triad. As a result of being in a low energy state, women may present with adverse health symptoms such as menstrual disturbances. The female athlete triad describes the interrelationships between low energy availability (with or without an eating disorder), menstrual disturbances and low bone density. The research suggests that 2% to 23% of female athletes suffer from all three of these (Goodwin et al., 2014; Melin et al., 2015; Pollock et al., 2010; Quah et al., 2009; Torstveit & Sundgot-Borgen, 2005a). However, athletes presenting with even one or two of these disorders are also considered to be at risk of the associated negative health consequences such as stress fractures, osteoporosis, increased injury risk, transient infertility, impaired endothelial function, fatigue, impaired recovery and decreased performance (Williams et al., 2017).

Although initially somewhat controversial, in 2014 the International Olympic Committee published a consensus statement suggesting the use of the more inclusive syndrome RED-S to replace the female athlete triad (Mountjoy et al., 2018). RED-S refers to “imparied phsyiological functioning caused by relative energy deficiency and includes but is not limited to, impairments of metabolic rate, menstrual function, bone health, immunity, protein synthesis and cardiovascular health” (Mountjoy et al., 2018, p. 687).

As is the case with menstrual disturbances, there is agreement in the literature that athletes in endurance sports, aesthetic sports and weight class sports are at greater risk of low energy availability, RED-S and the female athlete triad (Cobb et al., 2003; Goodwin et al., 2014; Melin et al., 2015; Meng et al., 2020; Quah et al., 2009). Athletes in these types of

sports are more likely to have a high drive for leanness or be under additional pressure to achieve and maintain a lower body weight and/or higher training volumes for appearance and performance reasons (Quah et al., 2009; Torstveit & Sundgot-Borgen, 2005a). Cross-country mountain biking is an endurance sport and athletes in this discipline of mountain biking are more likely to have higher training volumes and high drive for leanness, putting them at greater risk of low energy availability compared to downhill riders. Although there has been no research to date comparing the drive for leanness between cross-country and downhill mountain bikers, a recent review by Arriel, Souza, Sasaki, and Marocolo (2022) suggest a lower body mass and body fat percent can be an advantage to performance in professional cross-country mountain biking. Arriel et al. (2022) report an average body fat of 7% for professional male cross-country mountain bikers, whilst also highlighting that there is not enough research on female riders to draw any clear conclusions. Haakonssen, Martin, Jenkins, and Burke (2015) report elite Australian female cyclists competing in the Australian National Road Cycling Championships and the Oceania Championships are a weight-conscious population. Over 70% of cyclists had attempted to lower their body weight in the preceding 12 months and over half of female cyclists were consciously aware of wanting to reduce their body weight at least once a week (Haakonssen et al., 2015). Current body weight was significantly higher in sprinters and all-rounders compared to climbers and a trend was observed of the ideal body weight being lower in climbers than in sprinters (Haakonssen et al., 2015). This shows how different types of cyclists can have different body weights and perceptions of what their ideal body weight is. This is relevant to the differences in demands between downhill and cross-country mountain biking, particularly due to a large proportion of race time spent climbing in cross-country.

2.3. HORMONAL CONTRACEPTIVE USE

The research suggests that hormonal contraceptive use may differ between athletes and the general population. This is an important factor to consider due to the 'masking effect' of some hormonal contraceptives on the natural fluctuations of endogenous hormones. In these cases, the menstrual cycle or a period is unable to be used as an indicator of general health status, which can result in underlying health problems being missed (Clarke et al., 2021). A large epidemiological study of more than 194,000 women in the general population, reported 30% were hormonal contraceptive users (Cea-Soriano, García Rodríguez, MacHlitt, & Wallander, 2014). More recent research on elite athletes report current hormonal contraceptive use to range from 33% to 72% (Brown et al., 2021; Clarke et al., 2021; Coutinho et al., 2021; Findlay, MacRae, Easton, Forrest, & Whyte, 2020; Heather et al., 2021; Martin et al., 2018; Oxfeldt et al., 2020; Solli et al., 2020), and this is much higher if including those that are previous users.

Combined hormonal contraceptive methods, which contain estrogen and progestin, are more commonly used than progestin only methods with Oxfeldt et al. (2020) reporting 74% versus 26% respectively, from 186 Danish athletes across 21 different sports. Similarly, Martin et al. (2018) reported 69% of athletes in mostly hockey, football, rugby and athletics used combined hormonal contraceptive methods and 30% used progestin only. Studies consistently report the oral contraceptive pill or combined oral contraceptive pill as the most commonly used form of delivery making up about 65% to 80% of all hormonal contraceptive use (Clarke et al., 2021; Coutinho et al., 2021; Heather et al., 2021; Martin et al., 2018; Solli et al., 2020). Less common types of hormonal contraceptive methods include the implant, injections, intrauterine devices (IUDs) and vaginal rings. In this study IUDs will refer to only the hormonal type, not the non-hormonal Copper IUDs.

As with the general population, the primary reason for hormonal contraceptive use in athletes is contraception. However, second to this is for manipulating the menstrual cycle to either change the timing of a period or skip a period completely for training and/or competition. In elite athletes, the prevalence of period manipulation ranged from approximately 40% to 70% (Findlay et al., 2020; Heather et al., 2021; Martin et al., 2018; Oxfeldt et al., 2020), which is hardly surprising given approximately half of athletes perceive their menstrual cycle to negatively impact their performance (Armour et al., 2020; Bruinvels, Burden, Brown, Richards, & Pedlar, 2016). In addition, hormonal contraceptives are often used therapeutically to reduce menstrual cycle symptoms such as amount or duration of bleeding, pain and for improving skin or acne. Despite this, Clarke et al. (2021) found there to be no significant difference in menstrual cycle symptoms between hormonal contraceptive users and non-users. Equally, Oxfeldt et al. (2020) noted no difference in physical symptoms, but did find reduced emotional symptoms, both positive and negative. This suggests that hormonal contraceptives are not having the desired effect with physical symptoms and even though they may reduce the emotional lows across the menstrual cycle, they may also dull the emotional highs.

Martin et al. (2018) investigated the perceived side effects of hormonal contraceptive use in 430 elite athletes and reported about a third of users experienced positive side effects such as being able to predict and manipulate their cycle. This was much higher than negative side effects including weight gain (8%), irregular periods (4%) and poor skin (3%). However, Heather et al. (2021) found a higher incidence of negative side effects including weight gain (20%) and mood disturbance (21%). In addition, elite Australian football players cited negative side effects such as mood swings, weight gain and depression or anxiety as the main reason for stopping hormonal contraceptive use (Clarke et al., 2021). It is clear that there can

be large variability in women's responses to hormonal contraceptives. As such, Martin et al. (2018) recommend that each athlete is considered on a case-by-case basis.

2.4. MENSTRUAL CYCLE CHARACTERISTICS

Although menstrual cycle symptomology seems to be highly individualised, the majority of women experience symptoms that have potential to negatively impact training and performance. Studies indicate negative menstrual cycle symptoms are experienced by 77% to 93% of elite athletes and this is most commonly in the few days before and first few days of menstruation (Armour et al., 2020; Findlay et al., 2020; Heather et al., 2021; Martin et al., 2018; Oxfeldt et al., 2020; Solli et al., 2020).

Dysmenorrhea or painful periods are the most commonly reported period characteristic, affecting 48% to 83% of athletes (Armour et al., 2020; Brown et al., 2021; Coutinho et al., 2021; Findlay et al., 2020; Heather et al., 2021; Martin et al., 2018; Oxfeldt et al., 2020; Solli et al., 2020). This was defined differently in the research as either stomach pain, abdominal pain, period pain, abdominal cramps or the need to take pain relief for most periods. Menstrual cycle symptoms vary in severity and prevalence throughout the research. For example, in a study of 17 Commonwealth Games athletes competing in mostly rock climbing and weightlifting, the most common symptoms were abdominal cramps (71%), bloating (65%) and mood disturbance (59%) (Brown et al., 2021). Yet, in a larger study by Heather et al. (2021), which included athletes from a wider range of sports, the most common symptoms were pelvic pain (57%), increased fatigue (49%), low back pain (47%) and disrupted sleep (29%).

Menorrhagia or heavy menstrual bleeding is experienced by about a third of athletes and can lead to further health problems and increased psychological stress and anxiety

(Armour et al., 2020; Bruinvels et al., 2016; Findlay et al., 2020; Heather et al., 2021). Armour et al. (2020) found that athletes with heavy menstrual bleeding were more likely to report fatigue-related symptoms during their period. In addition, due to increased blood loss, these women are at increased risk of suffering from iron deficiency and anaemia (Bruinvels et al., 2016). Heavy menstrual bleeding may result in 'flooding through' protection which can cause additional stress, anxiety and distraction for athletes, particularly those required to wear clothing such as leotards in gymnastics or white shorts in rugby (Brown et al., 2021; Findlay et al., 2020). These women may also be unable to complete training sessions without needing to change protection. This would be even more of a problem for women taking part in sports in outdoor environments that may not allow for access to toilets. Elite rock climbers have reported additional concern around having their periods when training and competing at outdoor climbing locations which have no toilets, no facilities and nowhere to change and dispose of menstrual products (Brown et al., 2021).

Despite the majority of women experiencing negative menstrual cycle symptoms, Armour et al. (2020) observed very few athletes or coaches altered training to accommodate these symptoms. This finding was consistent in the research with only 13% to 22% of athletes reporting missed or altered training in relation to their menstrual cycle (Heather et al., 2021; Oxfeldt et al., 2020; Solli et al., 2020). At the higher end, 32% of athletes in a study of Australian football codes adapted their training, but this was typically only done so 1 to 5 times per year (Clarke et al., 2021). Limiting of daily activities is common with the general population in regards to menstrual cycle symptoms but this is not the case for athletes in regards to their scheduled training (Findlay et al., 2020). This could be due to the pressure athletes are under to perform, including expectations on them from themselves, coaches, and

sponsors, and being more accustomed to dealing with pain and discomfort as part of being an elite athlete. Most athletes override any bothersome or painful symptoms when required.

2.5. SUMMARY AND RESEARCH QUESTIONS

To summarise, while there is no research on the menstrual health of female mountain bikers, the research in other sports clearly shows that elite athletes are at increased risk of menstrual disturbances, low energy availability, RED-S and the female athlete triad. In addition, hormonal contraceptive use is higher in elite athletes than the general population and most often used for contraception, manipulating the cycle for training or competition and reducing negative menstrual cycle symptoms. While most women experience negative menstrual cycle symptoms, the specific symptoms and severity seems highly individualised and athletes are unlikely to adapt or alter their training in response to this.

Mountain biking is a highly complex sport that at an elite level, requires a highly adapted aerobic and anaerobic system, regardless of discipline. However, based on the research on athletes in endurance sports and sports with a high drive for leanness, cross-country riders could be at increased risk of menstrual disturbances and the associated long term health consequences. Ultimately, the menstrual health status of women in this sport is still unknown and leads to the following **research questions**:

1. What is the prevalence of menstrual disturbances in female World Cup mountain bikers?
2. What is the prevalence and reasons for use of hormonal contraceptives in female World Cup mountain bikers?
3. What are the menstrual cycle symptoms and period characteristics of riders and what is the perceived impact of these on their training and racing?

4. What impact does discipline (cross-country or downhill) have on menstrual health in World Cup mountain biking?

3. Research Design

This chapter describes the design adopted by this research to achieve the aims and objectives stated in **Chapter 1.3. PURPOSE**, that is to quantify the menstrual health status of female World Cup and World Championship Mountain bikers.

3.1. METHODOLOGY AND RESEARCH DESIGN

A cross-sectional online survey was used to collect data from the target population at a given point in time (see **Chapter 3.4. PROCEDURE AND TIMELINE**). Survey research enables data to be collected and analysed to produce numerical results. This is a common methodology used in previous menstrual health research on elite female athletes (Armour et al., 2020; Bruinvels et al., 2016; Coutinho et al., 2021; Heather et al., 2021; Meng et al., 2020; Oxfeldt et al., 2020; Solli et al., 2020). Online surveys are a quick and accessible method, enabling wide geographical reach. This was essential given the international nature of this research and participants' travel schedule for races. Additionally, this method was well-suited to the personal nature of the topic.

3.2. PARTICIPANTS

All female mountain bikers participating in the 2021 season of the UCI Mountain Bike World Cup Series, World Championships and Tokyo Olympics were eligible to take part in this research. This included riders competing in both UCI disciplines, cross-country and downhill, and in elite (aged > 23 years), under 23 (aged 19 to 22 years) and junior women (aged 17 to 18 years). It should be noted that in some cases, based on race results, younger riders can qualify and choose to race in a higher grade (i.e., an under 23 rider could race elite). Riders

needed to be > 16 years old to take part in this research. Screening questions were included in the initial part of the survey including:

1) Question 2 How old are you? (years)

2) for downhillers: Question 4 During the 2021 season, which of the following will you be competing in? (please indicate all that apply) World Cup, World Championships, None of the above, and

3) for cross-country riders: Question 5 During the 2021 season, which of the following will you be competing in? (please indicate all that apply) World Cup, World Championships, Tokyo Olympics, None of the above.

Any riders that were 16 years or younger were excluded from the analysis and any riders that selected "None of the above" to questions 4 or 5 received the following message: "As this survey is for women competing at the 2021 World Cups, World Championships and Tokyo Olympics, unfortunately you do not meet the required criteria. We are grateful for your interest in taking part in this research." These riders were then taken to the end of the survey. This exclusion criteria can be seen in a copy of the survey in **Appendix A Survey**.

This study was aimed at elite World Cup riders with an average (range) of 75 (36-104) riders in the elite World Cup cross-country races during the 2021 season and an average of 15 (14-15) riders in the elite World Cup downhill races. There was a potential maximum sample of elite riders in World Cups over both disciplines of 119 riders. An ideal sample size of 91 would provide a 95% confidence level in accuracy of results.

The 2021 Tokyo Olympics had only 38 cross-country riders, but this has a much harder selection criteria with limited spots available. The Olympics also only relate to cross-country as downhill is not an Olympic sport. The number of female riders competing at World Cup and World Championship level in downhill are consistently much lower than those competing

in cross-country. This difference is specific to the female category and is most likely due to the high-risk element of downhill, making this a more male dominated discipline.

3.3. SURVEY DESIGN

The study used a modified version of an existing validated survey already used in menstrual health research. To select the questionnaire, relevant surveys were found in the literature, either as provided in supplementary materials or through direct contact with researchers. Any surveys not in English were translated. Multiple surveys were compared, including the LEAF-Q (Low Energy Availability Frequency Questionnaire) (Melin et al., 2014) and Eating Disorder Inventory (Garner, 2004) as these had been cited as sections used in relevant surveys.

With permission, the Athlete Wins Survey by the WHISPA (Women's Health in Sport a Performance Advantage) group at High Performance Sport New Zealand (HPSNZ) was selected for use in this research (Heather et al., 2021). This was chosen due to being the most relevant to the research aims and being the most recently developed survey with up-to-date menstrual cycle terminology. Participants were provided with a reference to the research by the WHISPA group at HPSNZ, for further information.

For a copy of the final survey used in this study refer to **Appendix A Survey**. Main modifications to the Athlete Wins Survey included adding questions on mountain bike discipline, races they would be competing in and rank. Rank in this study was defined as the "best placing in a World Cup or World Championship race in the last two years". This time frame allowed for the disrupted travel and racing schedule experienced by riders in 2020 due to the global COVID-19 pandemic. Further modifications included removing questions

irrelevant to the research aims as well as removing the section titled "Pressures in Sport", to reduce the estimated completion time of the survey.

Questions included in the final survey related to: training volume, general health, age of menarche, current or history of menstrual disturbances, current or history of hormonal contraceptive use, reasons for hormonal contraceptive use, negative side effects of hormonal contraceptives, menstrual cycle symptoms, period characteristics, menstrual cycle regularity, tracking of the menstrual cycle, the perceived impact of the menstrual cycle on training and performance, unhealthy practices to achieve the "ideal" body type, whether or not they discuss their menstrual cycle with their Coach and whether they experienced any barriers to communication. Although a total of 48 questions were included in the survey, display logic was used so that only relevant questions were displayed to respondents based on their previous answers. Diagnosed illnesses, injuries or menstrual disturbances were those that had been clinically diagnosed by a doctor prior to completing the survey whereas undiagnosed had been self-diagnosed by the participant. Menstrual cycle regularity from the preceding 12 months was used to determine menstrual disturbances in non-hormonal contraceptive users and this was referred to as present or current menstrual disturbances, as done in research by Heather et al. (2021). For more details on survey questions refer to the full copy of the survey in Appendix **A Survey**.

The survey in this research was conducted using Qualtrics software (Qualtrics, 2021). Survey completion time was reduced to approximately 10 minutes as per Qualtrics software recommendations to reduce drop out or incomplete surveys. Additionally, the survey was amended using Qualtrics recommendations for survey flow and types of questions. The types of questions were mixed but predominantly multiple choice, with either single answer responses or multiple answers allowed. Besides questions to determine eligibility criteria,

participants were allowed to skip past questions. Participants were also able to move back through the survey to change any previously answered questions. The survey was tested for flow of questions, accurate display logic and was visually checked for face and content validity. Finally, the survey was translated into the following languages using Qualtrics inbuilt translations: French, Spanish, Italian, Polish, German, Slovenian, Czech and Slovak. These languages were chosen based on most riders coming from European countries.

3.4. PROCEDURE AND TIMELINE

Survey recruitment was done through social media, email, networking, and personal connections. The survey was initially shared on social media and available for completion from April 16th 2021, at the beginning of the World Cup race season. Prominent riders, organising bodies, organisations, teams, and those who had large social media followings and connections to the target population were contacted and asked if they could share the survey with riders who may be eligible to take part. Survey availability was set for a duration of approximately five months until September 30th 2021, following the final cross-country and downhill World Cup race of 2021.

An image was created for social media sharing, using the distinctive UCI rainbow stripes (see **Figure 2**). A brief summary of the research was written to be shared alongside this, including eligibility criteria and an anonymous link to complete the survey. Information sharing and knowledge dissemination is an integral aspect of sport education and communication. Key athletes were contacted and asked the best method of communication or dissemination of information to female World Cup athletes and the mountain bike community. Instagram was suggested for this, and some key athletes shared this on their

Instagram pages. Instagram was the main social media platform used for advertising and sharing the survey, due to this being the most popular with the target population.

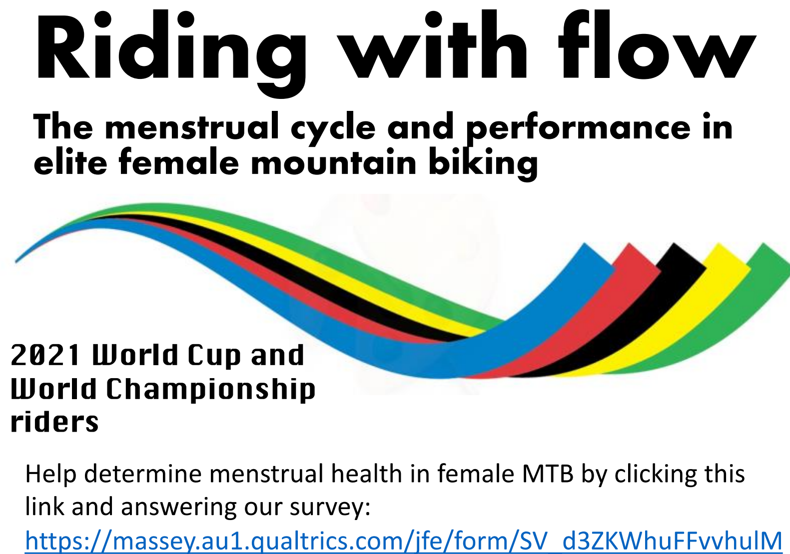

Figure 2. *Image used for social media sharing and advertising of the survey.*

3.5. ETHICS

A brief summary of the research aims was provided to participants in the introductory section of the survey. Confidentiality was of the utmost importance and upheld through anonymising of results and protection of participant information. Participants were informed that by submitting their survey they were providing their consent to take part in this research. Contact details for the lead researcher were provided to participants.

This research was recorded in the Annual Report of the Massey University Human Ethics Committee. Ethics Notification Number: 4000024067. This project was evaluated by peer review and judged to be low risk. Consequently, it was not reviewed by one of the University's Human Ethics Committees. The researchers named in this document were responsible for the ethical conduct of this research.

3.6. ANALYSIS

3.6.1 Exporting of data

All survey responses were visually checked. Custom filters were applied to the Qualtrics data and analysis tool. Filters were set to only include those responses that were 100% completed and in which respondents had selected they were competing in at least one of the following races of the 2021 season: World Cups, World Championships, or the Tokyo Olympics. Since respondents were allowed to skip questions, completed surveys were defined as having 'clicked through' to the end of the survey even if they had not answered all questions. Surveys that had been stopped part way through were incomplete and excluded. Any surveys completed by those that were < 16 years old were also excluded.

All completed responses that fit the criteria were deemed valid responses and exported from Qualtrics into Microsoft Excel for further analysis. Questions were divided into categories based on general themes: Q2-10 participant characteristics, Q11-21 general health, Q22-26 hormonal contraception, Q27-34 the menstrual cycle, Q35-44 the menstrual cycle and training, Q45-48 socio-cultural factors. For examples of questions in each of these categories refer to **Table 1.**

Table 1. *Categories of survey questions based on themes and examples of questions in each.*

Category	Question numbers	Examples
Participant characteristics	Q2-Q10	Q3. Please indicate your main MTB discipline Q7. Over the past two years, what has been your best placing in a World Cup or World Championship race?
General health	Q11-Q21	Q13. Have you ever been diagnosed with iron deficiency and/or anaemia? Q17. Have you ever experienced a period (menstrual bleed)?
Hormonal contraceptives	Q22-Q26	Q22. Have you ever used hormonal contraception (for any reason)? Q23. Which hormonal contraception are you currently using, or have you most recently used?
The menstrual cycle	Q27-Q34	Q27. How many periods have you had in the last 12 months? Q31. Relating to your menstrual cycle do you experience any of the following symptoms? (please select all that apply)
The menstrual cycle and training	Q35-Q44	Q37. In the last six months have you missed or modified any training due to menstrual cycle related symptoms? Q39. Relating to your menstrual cycle what symptoms have caused you to miss or modify training? (please select all that apply)

Category	Question numbers	Examples
Socio-cultural factors	Q45-Q48	Q45. Have you used any of the following to try to obtain the "ideal" body for performance or appearance reasons? (please select all that apply) Q47. Do you experience any barriers communicating menstrual-related issues with support staff?

3.6.2. Data preparation

Using Excel, all data were checked for correct reporting, coding, and numbering. Data were reorganised based on question type. For single response, categorical, binary (yes/no) questions, coding was applied with 1 = yes and 0 = no. For questions with multiple categorical responses, these were separated into columns to make each categorical response a single binary (yes = 1, no = 0) answer. Single categorical but ordinal responses maintained the text answer but coding A, B, C… was applied to indicate order. As part of the data cleaning process, any missing values were filled with NA, and the redundant "none" responses were removed.

3.6.3. Data analysis and statistical analysis

Using Excel, frequency tables were used to examine participant responses to most survey questions. Text box entries were recorded separately. Data were presented as mean (±SD) for numerical variables, or number and percentages with 95% confidence intervals for categorical variables.

For further analysis, undiagnosed oligomenorrhea (Q12), undiagnosed amenorrhoea (Q12), diagnosed oligomenorrhea (Q11) and diagnosed amenorrhea (Q11) were grouped together to create a new variable: menstrual disturbances. See **Figure 3.**

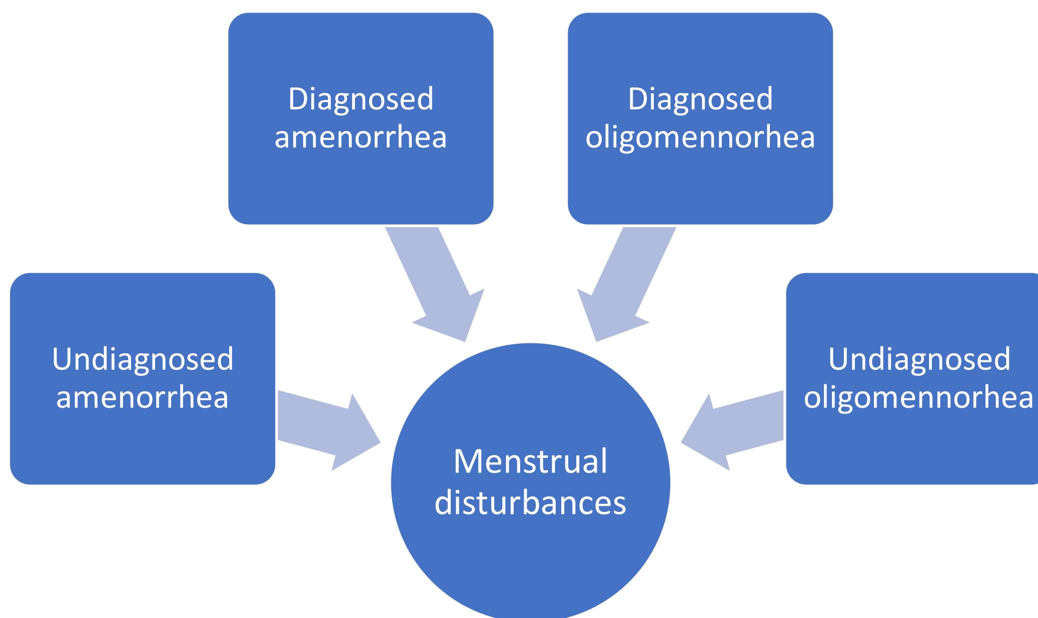

Figure 3. *Combining of variables to create a new variable: menstrual disturbances. Diagnosed refers to medically diagnosed by a doctor and undiagnosed is self-diagnosed by the athlete.*

Question 11 was separated out into diagnosed illnesses, injuries, and mental health. Diagnosed illnesses (Q11, Q13, Q21), menstrual cycle symptoms (Q31), negative side effects of hormonal contraceptive use (Q26), disordered eating practices (Q45) and barriers to communication (Q48) were converted to a count-based metric to indicate a level of severity. Delayed menarche, defined as being 16 years or older when experiencing their first period, was a new variable created based on the answer from Question 18. Heavy menstrual bleeding was self-determined and defined in this study by responding with two or more answers from

Question 34. This definition was based off that used by Bruinvels et al. (2016) in previous research on heavy menstrual bleeding in elite and non-elite athletes.

For sub-group analysis, participants were grouped into the following: present hormonal contraceptive users and naturally cycling women, cross-country riders and downhill riders, Junior (U19) and U23/Elite (combined category), and U23/Elite cross-country and U23/Elite downhill riders who have placed in the top 10 (renamed as World Class XCO and World Class DH). The separation of the U23/Elite and Junior riders was important as these represent different levels and abilities. Although U23 and elite riders race separately in cross-country World Cups and World Championships, based on performance, some of the best riders in the U23 category were eligible to race in the more competitive elite category. These riders could then choose to race in elite or U23 at different races throughout the season. This is not uncommon in cross-country. In downhill, the U23 and elite grades are often combined due to lower numbers. This provides the rationale for combining the U23 and elite categories for data analysis, into the group U23/Elite. The World Class XCO and World Class DH grouping is further isolating and comparing the riders in this study that are at the highest level in their sport. This also made these groups more similar in terms of ability and level in their respective disciplines, which provided for more meaningful comparisons.

Data were imported into R studio (RStudio, 2021) for statistical analysis, with a *p* value of < 0.05 set as the level of statistical significance. Non-parametric statistical tests included the Wilcoxon signed-rank test for ordinal variables with dependent measures and the Mann Whitney *U* test for ordinal variables with independent measures. Pearson's Chi-squared test examined the differences between binary categorical variables, with Fisher's exact test used in cases where cell counts were less than five. The Kruskal-Wallis rank sum test was used to

test for statistical significance in ordinal categorical data across three or more levels of independent measures.

Parametric tests used for continuous variables included the Welch Two Sample *t*-test for independent samples with two levels, and a One-way ANOVA (analysis of variance) for independent samples with three or more levels. Details of statistical tests used can be found in **Appendix B Supplementary table 1**. Where appropriate, 95% confidence intervals were calculated and reported as error bars on figures.

4. Results

The findings of this research are presented in this section, as they relate to the research objectives (refer to **Chapter 1.3. PURPOSES**). A brief description of the participant characteristics is provided, followed by results on 1) menstrual disturbances and general health, 2) hormonal contraceptive use, 3) menstrual cycle characteristics, including tracking of the cycle and barriers to communication and 4) a comparison of cross-country and downhill. Statistical tests used are detailed in **Appendix B Supplementary table 1**. Overall, the results suggest that menstrual disturbances were experienced by over half of all riders and negative menstrual cycle symptoms were experienced by most.

4.1. PARTICIPANT CHARACTERISTICS

Seventy-six valid survey responses were included for analysis in this study, which was lower than the ideal calculated sample size of 91 for an accuracy of results with a 95% confidence interval. With an estimated possible number of 119 riders in the targeted races, the valid responses make up 64% of the target population. Respondents were 28% (*n*=21) junior riders (junior women/U19), 72% (*n*=55) U23/Elite, 85.5% (*n*=65) cross-country riders and 14.5% (*n*=11) downhill riders, (**Figure 4** and **Figure 5**). Riders had a mean age of 22 ±5 years with a range of 25, upper limit of 42 and lower limit of 17 (lower limit set by eligibility criteria). Cross-country riders had an average age of 23 ±5 years and downhill riders an average of 22 ±5 years. The average age of menarche was 13.6 ±1.5 years.

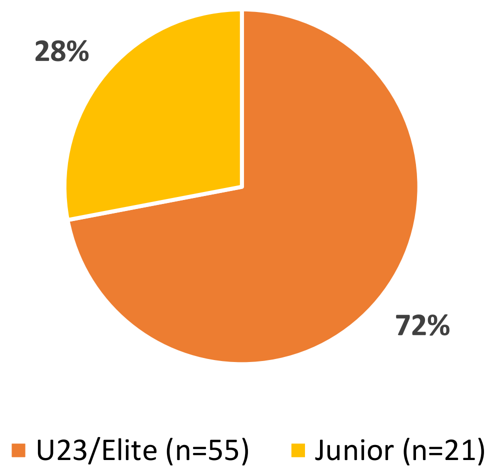

Figure 4. *Percent of riders at each level (n=76).*

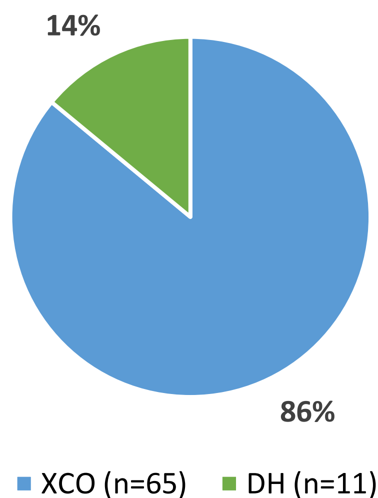

Figure 5. *Percent of riders in each mountain bike discipline (n=76).*

At the time of taking the survey, 92% (*n*=70) were competing in World Cups, 62% (*n*=47) in World Championships and 9% (*n*=7) in the 2021 Tokyo Olympics. Most riders (87%, *n*=66) had a competition age of five years or less at World Cup level, while 11% (*n*=8) had been competing at this level for 6-10 years and only 3% (*n*=2) had done so for longer than 10 years (**Figure 6**). Weekly training hours tended to be overall higher outside of competition

phase (no races coming up or having just been) than in competition phase (races coming up or just been), with more participants falling into higher-volume training categories ($p < .001$) (**Figure 7**).

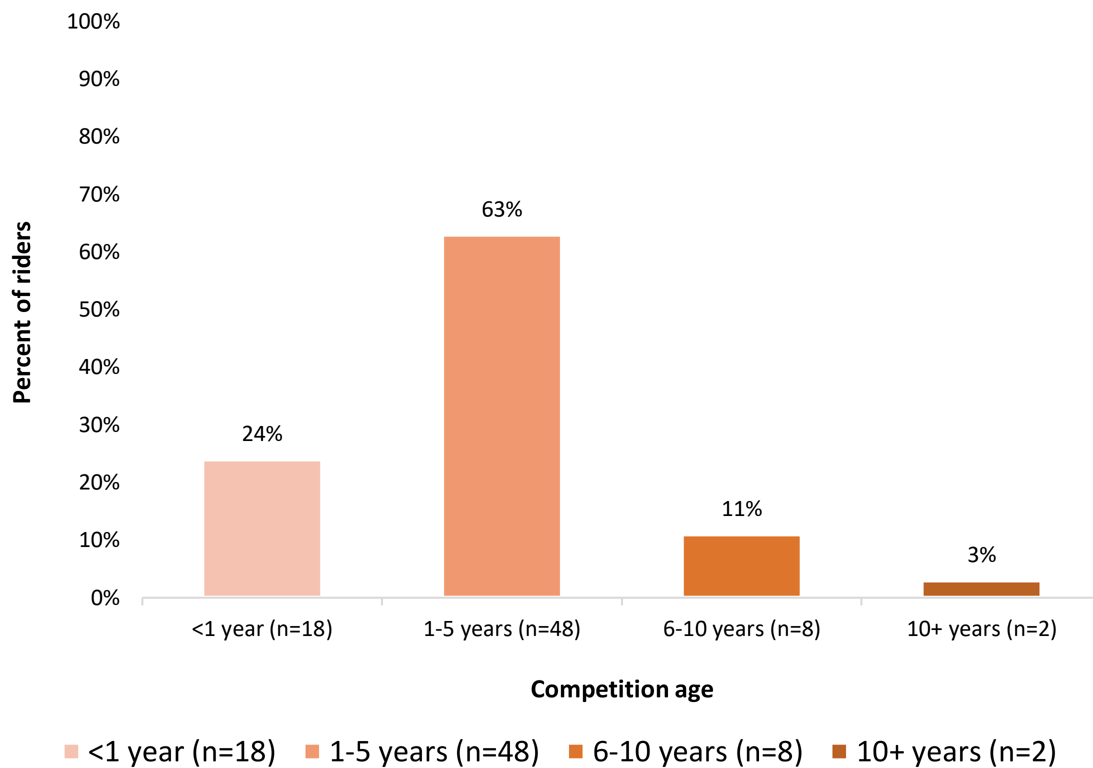

Figure 6. *Riders by competition age - time spent competing at World Cup or World Championship level (n=76).*

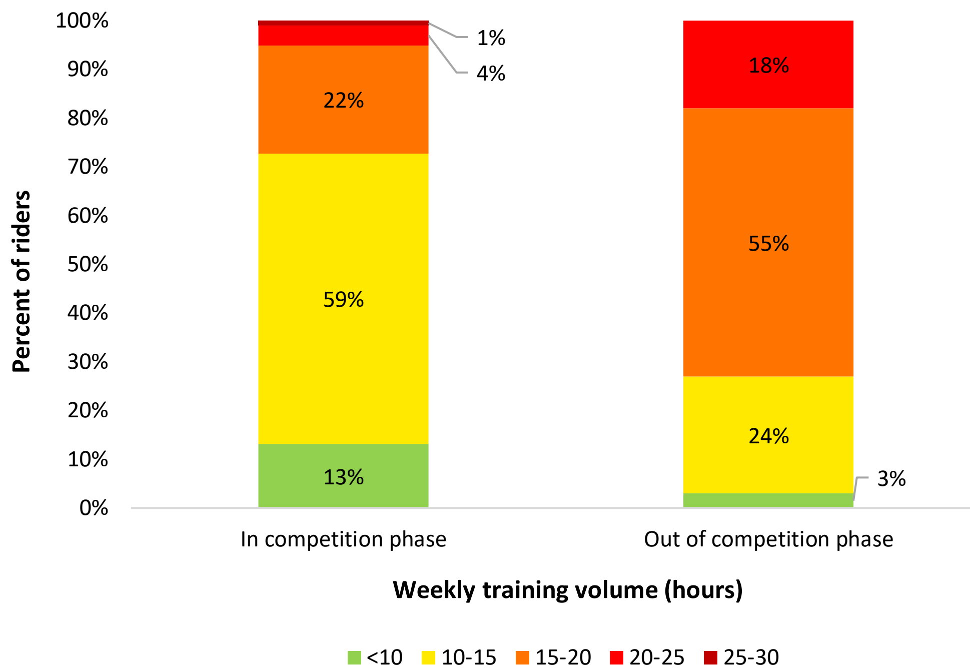

Figure 7. *Weekly training volume (hours), in competition phase and out of competition phase. n=76.*

4.2. MENSTRUAL DISTURBANCES AND GENERAL HEALTH

A total of 58% of all riders reported present or historical menstrual disturbances including oligomenorrhea or amenorrhea (**Table 2**). Undiagnosed menstrual disturbances were approximately double that of diagnosed menstrual disturbances. Undiagnosed menstrual disturbances were self-diagnosed, see Q12 in the survey in **Appendix A Survey**. Diagnosed menstrual disturbances were medically diagnosed by a Doctor, See Q11 in the survey in **Appendix A Survey**. There were no significant differences in menstrual disturbances regarding age or discipline (**Figure 8**). In addition, there were no significant differences in menstrual disturbances in relation to weekly training volume both in competition phase (**Figure 9**) and out of competition phase (**Figure 10**). Diagnosed amenorrhea was significantly higher in those with a previous diagnosis of RED-S or the female athlete triad (Fisher's *P*, p = 0.010) and undiagnosed amenorrhea was significantly higher in those who engaged in a greater

number of disordered eating practices ($t(74)= -2.72$, $p=0.008$). There were no other significant relationships observed between menstrual disturbances and other diagnosed illnesses or injuries. These results on menstrual disturbances combine present and historical menstrual disturbances with an open-ended time frame.

Table 2. *Present and historical menstrual disturbances. Respondents allowed to answer more than one type, but were only counted once for totals. n=76.*

Menstrual disturbances	Count	Prevalence
Menstrual disturbances		
Diagnosed	19	25%
Undiagnosed	44	58%
Total	44	58%
Amenorrhea		
Diagnosed	12	16%
Undiagnosed	24	32%
Total	26	34%
Oligomenorrhea		
Diagnosed	10	13%
Undiagnosed	34	45%
Total	36	47%

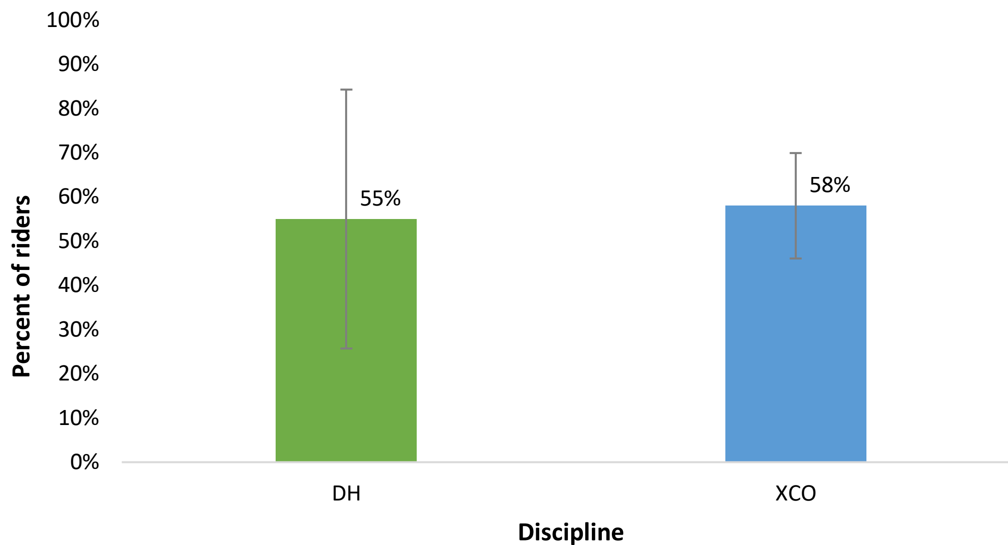

Figure 8. *Prevalence of present or historical menstrual disturbances by discipline. Error bars show 95% confidence intervals [based on the standard error for a proportion]. DH n=11, XCO n=65.*

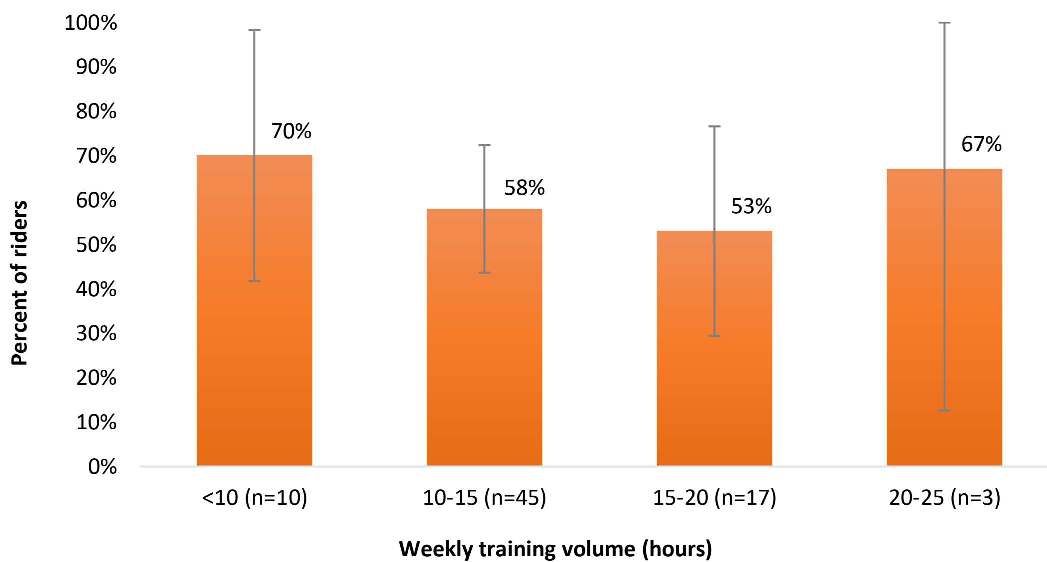

Figure 9. *Prevalence of present or historical menstrual disturbances by weekly training volume (hours) in competition phase. Error bars show 95% confidence intervals [based on the standard error for a proportion]. n=76.*

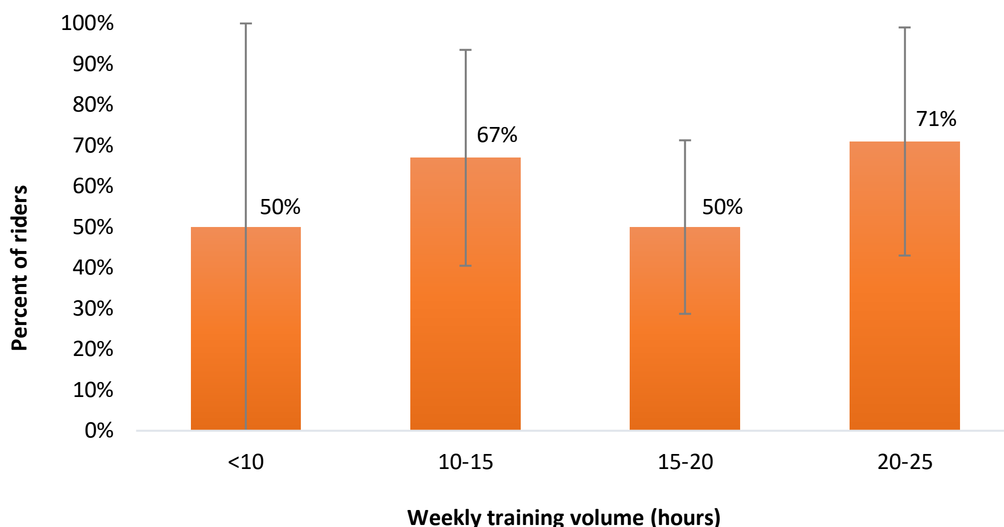

Figure 10. *Prevalence of present or historical menstrual disturbances by weekly training volume (hours) out of competition phase. Error bars show 95% confidence intervals [based on the standard error for a proportion]. n=76*

Twelve percent of riders (*n*=9) met diagnostic criteria for delayed menarche (i.e., > 15 years old when experiencing their first period). For those not using hormonal contraceptives at the time of taking the survey (75%, *n*=57) menstrual cycle regularity for the last 12 months showed 23% (*n*=13) fit the criteria for oligomenorrhea and 7% (*n*=4) for amenorrhea. This gave a total for present menstrual disturbances in non-hormonal contraceptive users as 30% (*n*=17), with present menstrual disturbances in this research referring to menstrual disturbances in the preceding 12 months.

The most prevalent clinically diagnosed illnesses and injuries were iron deficiency/anaemia (37%, *n*=28), concussion (24%, *n*=18), asthma (18%, *n*=14) and depression/anxiety (17%, *n*=13) (**Table 3**). Concussions were significantly higher in downhill riders than cross-country riders (χ^2(1, *n*=76)=4.93, *p* =0.026). Additionally, those with a

previous or current diagnosis of depression or anxiety were more likely to have diagnosed injuries including concussions or stress fractures (χ^2 (1, *n* = 76) = 6.30, *p* = 0.012).

Disordered eating had been diagnosed in 15% (*n*=11) of riders (**Table 3**) and was significantly higher in those with diagnosed low bone density (Fisher's *P*, *p* = 0.02) and RED-S or the female athlete triad (Fisher's *P*, *p*=0.007). When asked if they engaged in any disordered eating practices to achieve the "ideal" body type for appearance or performance reasons, 46% (*n*=35) reported dieting or very restrictive nutrition practices and 26% (*n*=20) reported training on rest days (**Table 4**). Further, those who engaged in a greater number of disordered eating practices (**Table 4**) also had a higher proportion of diagnosed RED-S or the female athlete triad (*t* (7.09) = -2.56, *p*=0.037). A trend was observed with higher weekly training hours during competition phase and a greater number of disordered eating practices, but this was not significant.

Medically diagnosed RED-S or the female athlete triad was prevalent in 9% of riders (*n*=7) and associated with higher weekly training volume both during (*W*=80.5, *p*=0.001) and out of competition phases (*W*=84, *p*=0.001). RED-S or the female athlete triad was also higher in those with diagnosed low bone density (Fisher's *P*, *p*=0.007) or hypothyroidism (Fisher's *P*, *p*=0.04) and in riders who had been competing at this level for longer (i.e., competition age) (*W*=125, *p*=0.014).

Table 3. *Prevalence of clinically diagnosed illnesses and injuries. Multiple responses allowed so prevalence adds to more than 100%. n=76.*

Diagnosed illness or injury	Count	Prevalence
Illness		
Iron deficiency or anaemia	28	37%
Asthma	14	18%
Depression or anxiety	13	17%
Disordered eating	11	15%
RED-S or the female athlete triad	7	9%
Hypothyroidism	4	5%
Polycystic ovarian syndrome	3	4%
Low bone density	2	3%
Other	4	5%
Injury		
Concussion	18	24%
Stress fracture	4	5%

Table 4. *Prevalence of disordered eating practices. n=76.*

Disordered eating practices	Count	Prevalence
Dieting or very restrictive nutrition practices	35	46%
Training on rest days	20	26%
Use of medication or supplements	6	1%
Vomiting or purging	3	4%
Use of laxatives	1	8%
None	32	42%

4.3. HORMONAL CONTRACEPTIVE USE

Twenty five percent (*n*=19) of riders were current hormonal contraceptive users, and another 25% (*n*=19) were previous hormonal contraceptive users (**Table 5**). There were no significant differences in hormonal contraceptive use with age, discipline, or training volume, during competition phase or out of competition phase. The combined oral contraceptive pill (COCP) was the most used type (53%, *n*=20), primarily for contraception (66%, *n*=25), to enhance period regularity (34%, *n*=13) and to reduce period pain (24%, *n*=9) (**Table 5**). The most reported side effects of hormonal contraceptives included weight gain (40%, *n*=15), mood disturbance (37%, *n*=15) and light or absent periods (26%, *n*=10) (**Table 6**).

Table 5. *Prevalence of hormonal contraceptive use (n=76), type (n=38) and reason for use (n=38).*

Hormonal contraceptive use	Count	Prevalence
Current	19	25%
Previous	19	25%
Never	38	50%
Type:		
COCP	20	53%
Hormonal IUD	9	24%
Progesterone-only pill	7	18%
Depot injection	2	5%
Jadelle implant	2	5%
Reason:		
Contraception	25	66%
Enhance period regularity	13	34%
Reduce period pain	9	24%
Period manipulation	6	16%
Reduce acne	6	16%
Unsure; prescribed by doctor	2	5%

Table 6. *Prevalence of hormonal contraceptive side effects. n=38.*

Reported side effects	Count	Prevalence
Weight gain	15	40%
Mood disturbance	14	37%
Light or absent periods	10	26%
Performance deficit	8	21%
Heavy periods	7	18%
Acne	5	13%
Breast tenderness	5	13%
Migraines	3	8%
Other	9	24%
Nil	7	18%

4.4. MENSTRUAL CYCLE CHARACTERISTICS

All women, irrespective of hormonal contraceptive use, were able to answer questions relating to menstrual cycle characteristics. The majority (89%, *n*=68) of riders reported menstrual cycle symptoms that could potentially have a negative impact on training and performance (**Table 7**). The most prevalent were pelvic pain (67%, *n*=51), low back pain (53%, *n*=40), increased fatigue (49%, *n*=37) and headaches (37%, *n*=28). There were no significant age, discipline, or training volume differences in relation to the number of menstrual cycle symptoms experienced. Thirty two percent (*n*=24) of riders reported taking pain relief during menstruation, which could indicate dysmenorrhea (painful periods). When asked if they considered their periods to be heavy, 24% (*n*=18) responded with “yes”. This

is consistent with 29% (*n*=22) of riders reporting period characteristics that fulfill the diagnostic criteria for menorrhagia or heavy menstrual bleeding (**Table 7**).

Table 7. *Menstrual cycle characteristics. Multiple responses allowed for symptoms and period characteristics, so total prevalence for these variables add to more than 100%. n=76.*

Menstrual cycle characteristics	Count	Prevalence
Menstrual cycle symptoms		
Pelvic pain	51	67%
Low back pain	40	53%
Increased fatigue	37	49%
Headaches	28	37%
Disrupted sleep	18	24%
Pain in thighs	15	20%
Nausea and vomiting	12	16%
Nil	8	11%
Other	22	29%
Requiring pain relief during menstruation		
Yes	24	32%
No	52	68%
Period characteristics		
Considered heavy	18	24%
Not considered heavy	56	76%
Need to frequently change protection	24	32%
Passing large blood clots	18	24%
Flooding through protection	15	20%
Struggle to complete training without changing protection	9	12%
Required to use double protection	6	8%

In the last six months, about a third (38%, *n*=29) of riders experienced disruption to training due to menstrual cycle symptoms, with the most reported symptom being fatigue (69%, *n*=20), severe pain or cramps (66%, *n*=19) and a lack of motivation (55%, *n*=16) (**Table 8**). However, most riders (92%, *n*=8) had not missed a race in the last four years due to menstrual cycle symptoms. This analysis included women not on hormonal contraceptives and women on hormonal contraceptives.

Beliefs about the impact of the menstrual cycle on performance were mixed, with about a third (37%, *n*=28) believing their performance to be decreased during menstruation and another third (33%, *n*=25) being unsure. A smaller number (12%, *n*=9) believed they performed better when menstruating (**Table 8**).

Table 8. *The menstrual cycle in relation to training and racing. Multiple responses allowed for non-binary response questions, so total prevalence for these add to more than 100%. n=76.*

The menstrual cycle with training and racing	Count	Prevalence
In the last 6 months:		
Has not missed or modified training	47	62%
Has missed or modified training (1 to 5 times)	29	38%
Reasons for missed training:		
Fatigue	20	69%
Severe pain or cramps	19	66%
Lack of motivation	16	55%
Low mood	12	41%
Body aches	8	28%
Headache	7	24%
Other	10	34%
In the last 4 years:		
Has not missed a race	70	92%
Has missed a race	6	8%
Beliefs:		
Improved performance when menstruating	9	12%
Decreased performance when menstruating	28	37%
Improved performance when ovulating	8	11%
Decreased performance when ovulating	10	13%
No impact on performance	13	17%
Unsure	25	33%

Most riders tracked their menstrual cycle (79%, *n*=60), primarily using a smart phone App (**Table 9**). This question was available for all women, those not using hormonal contraceptives and those using hormonal contraceptives, as was done in research by Heather et al. (2021). Given 57 women were naturally cycling, but 60 women tracked their cycle, this means that some women using hormonal contraceptives still tracked their cycle. When asked about whether they discuss their menstrual cycle with their coach, 65% (*n*=49) of riders said that they did talk to their coach and 35% (*n*=26) of riders didn't (**Table 10).** Only one rider chose not to answer this question and was excluded from the results on this. When asked about whether they experienced barriers to communication with support staff on menstrual cycle issues, although most riders didn't, 26% (*n*=19) of riders said that they did. Of these 19 riders who did, this was almost always with male coaches (95%). Other support staff riders did not feel comfortable talking to included male strength and conditioners (37%), male sports scientists (26%), male nutritionists (21%), male doctors (21%) and male physiotherapists (16%). No riders reported issues communicating with female support staff. Regarding the perceived barriers to communication, the most prevalent was the stigma of the topic (74%), gender of the staff (63%) and the lack of staff knowledge on this topic (53%) (**Table 10**).

Table 9. *Prevalence of riders who track their menstrual cycle (n=76) and method used (n=60). Multiple responses allowed for method used so prevalence adds to more than 100%.*

Tracking of the menstrual cycle	Count	Prevalence
Does track their menstrual cycle	60	79%
Does not track their menstrual cycle	16	21%
Method used		
Training software	13	22%
Smart phone App	43	72%
Paper or electronic diary	11	18%

Table 10. *Communication with support staff about the menstrual cycle, including whether they talk with their coach (n=75), experience barriers (n=74) and what these perceived barriers are (n=19).*

Communication around the menstrual cycle	Count	Prevalence
Discusses with Coach	49	65%
Does not discuss with Coach	26	35%
Experiences barriers to communication	19	26%
Does not experience barriers to communication	55	74%
Perceived barriers to communication		
Stigma of topic	14	74%
Gender of staff	12	63%
Lack of staff knowledge	10	53%

4.5. CROSS-COUNTRY VERSUS DOWNHILL

This section shows results when comparing cross-country and downhill riders who were U23/Elite and had a top 10 ranking (*n*=22). These two groups will be referred to as World Class XCO (*n*=15) and World Class DH (*n*=7), representing the highest-level athletes in this study. Although there were some interesting and substantial differences observed between disciplines at this level, the small sample size meant that none of the differences were statistically significant. Nevertheless, the magnitude of some of the observed differences suggests that further exploration may be warranted. Details of statistical tests used can be found in **Appendix B Supplementary table 1**.

World Class DH riders were on average older than World Class XCO riders with average ages 25 ±4 and 22 ±3 respectively. The lower age limit for both groups was set by the selection criteria of level, making this 19 years old. Thirty-one and 19 years old were the upper limits for age in the World Class DH and World Class XCO groups, respectively.

Out of competition phase, World Class XCO riders tended to have higher weekly training volumes than World Class DH riders, with a higher percentage of riders in the categories with 15 or more hours per week (**Figure 11**). However, there were less differences in training volume during the competition phase (**Figure 12**).

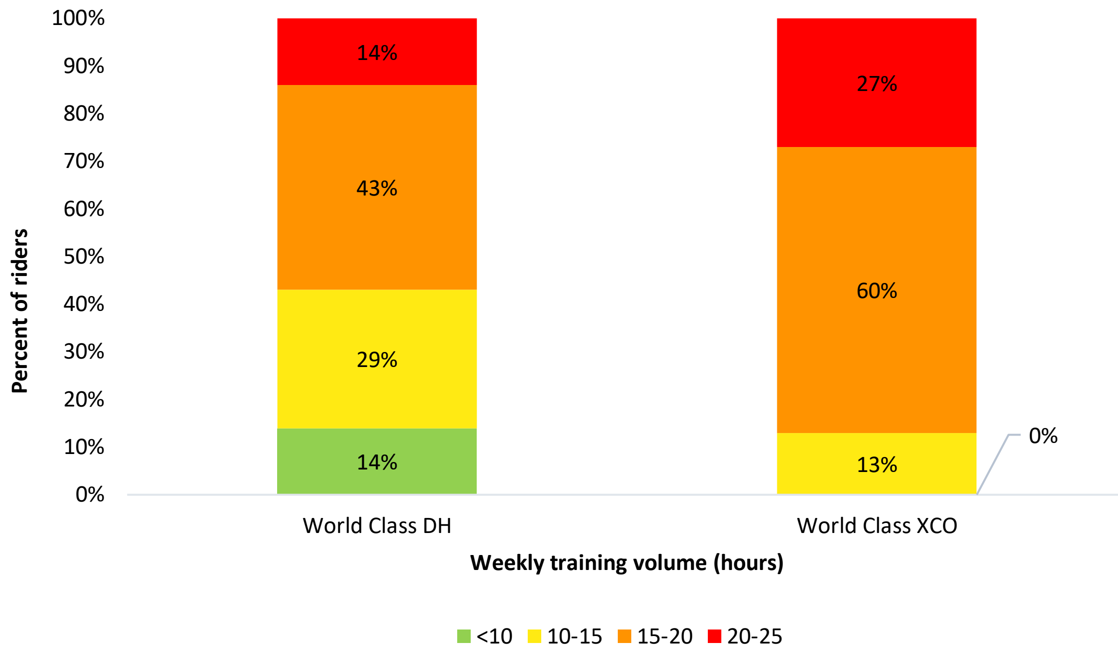

Figure 11. *A comparison of weekly training volume (hours) between World Class DH (n=7) and World Class XCO (n=15), out of competition phase.*

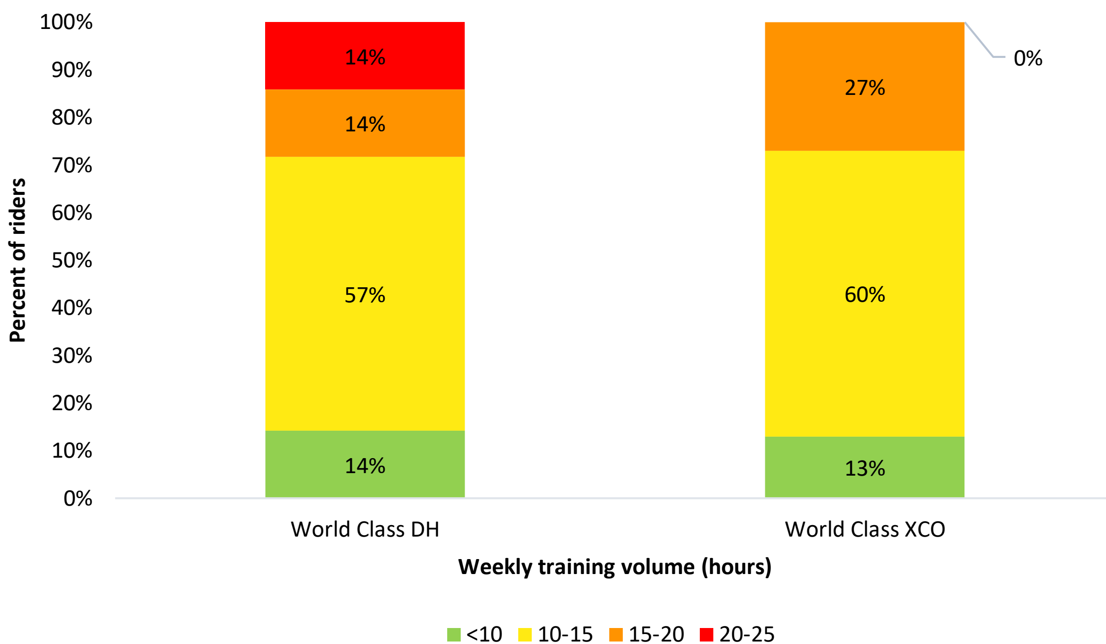

Figure 12. *A comparison of weekly training volume (hours) between World Class DH (n=7) and World Class XCO (n=15), in competition phase*

Although not significant, the proportion of present or historical amenorrhea (total of undiagnosed and diagnosed) was higher in World Class XCO than World Class DH and present or historical oligomenorrhea (total of undiagnosed and diagnosed) was higher in World Class DH than World Class XCO (**Figure 13**). The total prevalence of present or historical menstrual disturbances (undiagnosed and diagnosed) showed no significant differences between World Class DH and World Class XCO groups (**Figure 13**). Total prevalence of menstrual disturbances was slightly higher in these groups though when compared to data from all riders; 71% World Class DH and 67% World Class XCO versus 58% all riders. Data on present or historical menstrual disturbances was collected with an open-ended time frame.

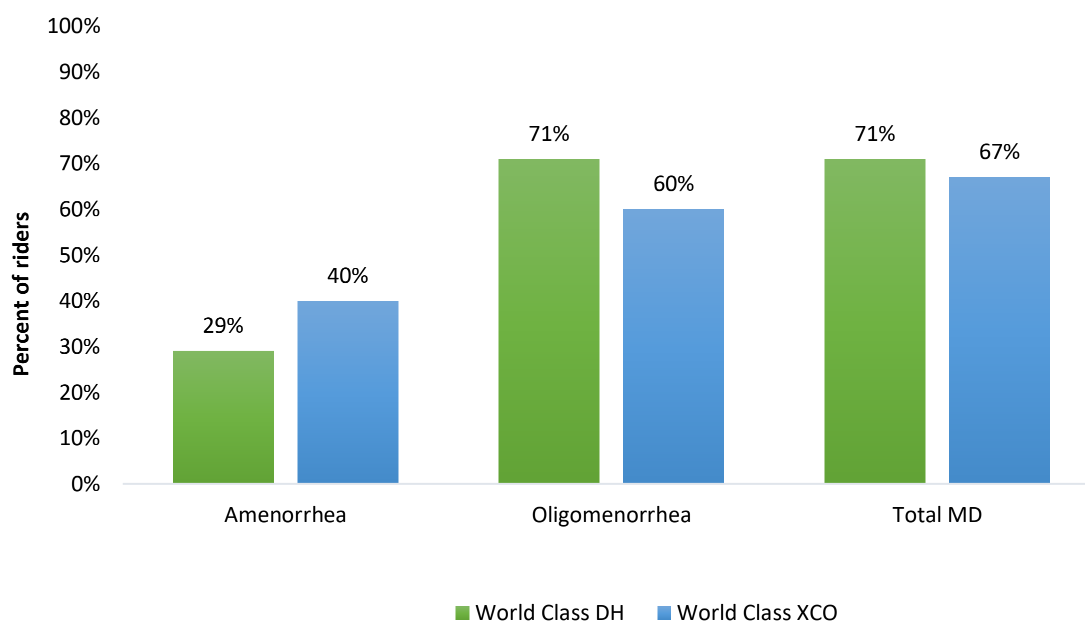

Figure 13. *A comparison of present and historical menstrual disturbances between World Class DH (n=7) and World Class XCO (n=15). Prevalence includes undiagnosed and diagnosed. Each responder could report more than one type of menstrual disturbance but was only counted once in the total menstrual disturbance group. Confidence intervals are excluded due to the small sample size.*

The average number of diagnosed illnesses or injuries were about the same for World Class XCO and World Class DH riders, at 1.3 and 1.4 respectively. Medically diagnosed disordered eating and RED-S or the female athlete triad were only reported by World Class XCO riders, with none of the World Class DH riders experiencing these diagnoses (**Figure 14**). Iron deficiency or anaemia was higher in World Class XCO than World Class DH and World Class DH had a higher proportion of depression or anxiety (**Figure 14**). The most pronounced difference was seen in concussion, reported in 57% of World Class DH compared to 13% of World Class XCO (**Figure 14**).

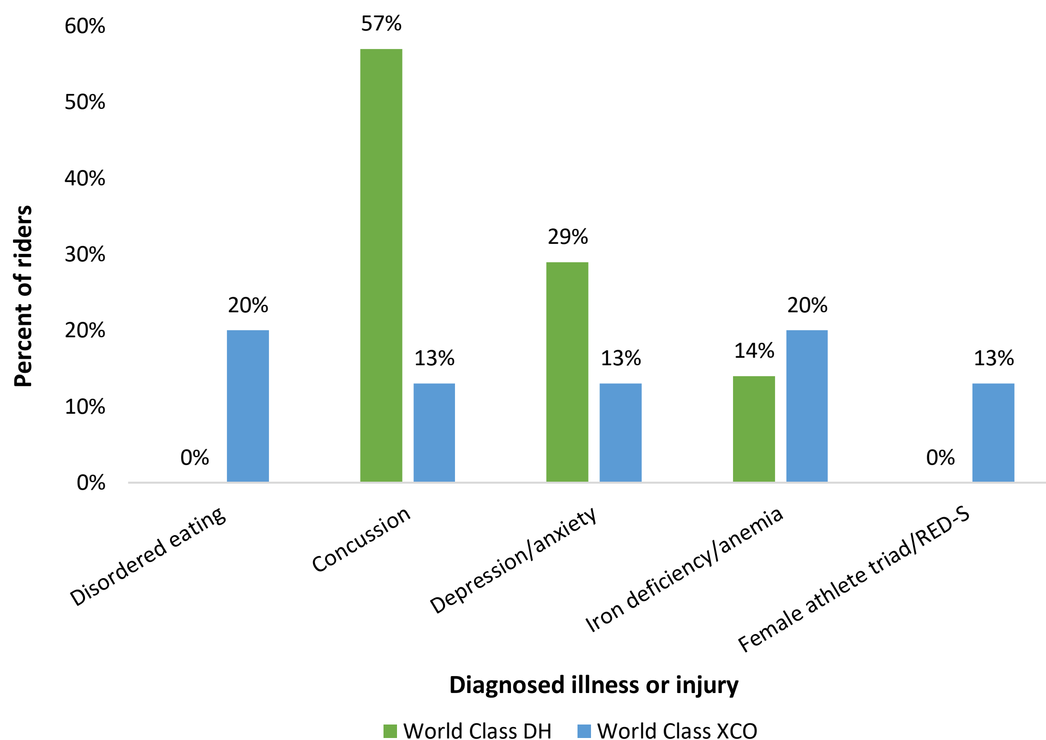

Figure 14. *A comparison of present and historical clinically diagnosed illnesses and injuries in World Class DH (n=7) and World Class XCO (n=15). Confidence intervals are excluded due to small sample size.*

Current hormonal contraceptive use was about the same between groups, with 29% of World Class DH and 33% of World Class XCO. However, World Class DH riders reported more negative side effects related to their current or previous hormonal contraceptive use. There was a non-significant trend for a greater proportion of World Class DH riders (57%) than World Class XCO (13%) riders to meet the diagnostic criteria for heavy menstrual bleeding (**Figure 15**). World Class DH riders also experienced more menstrual cycle symptoms than World Class XCO riders (**Figure 16**). Unsurprisingly, more World Class DH (73%) than World Class XCO (27%) riders experienced disruption to training due to menstrual cycle symptoms (**Figure 17**). Specifically, this refers to missing or modifying a training session 1 to 5 times in the last six months due to negative menstrual cycle symptoms. Results for heavy menstrual bleeding and menstrual cycle characteristics included women using hormonal contraceptives and women not using hormonal contraceptives.

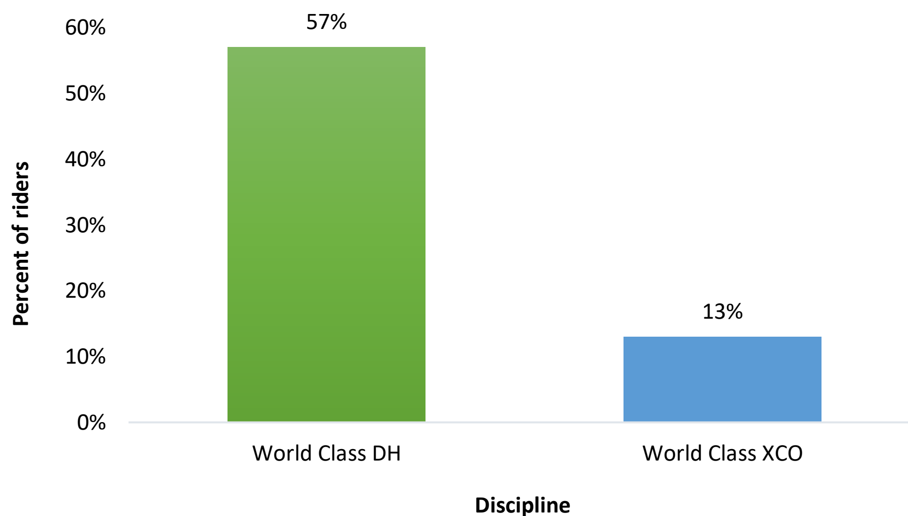

Figure 15. *A comparison of the prevalence of heavy menstrual bleeding between World Class DH (n=7) and World Class XCO (n=15). Confidence intervals are excluded due to small sample size.*

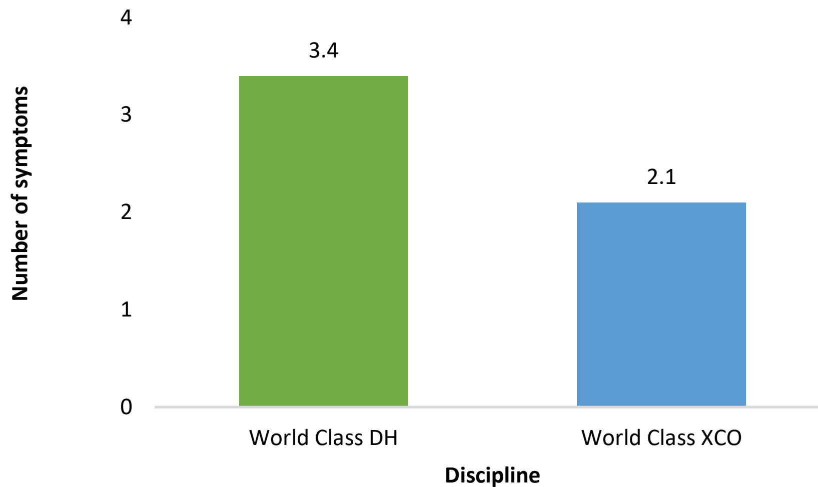

Figure 16. *A comparison of the average number of menstrual cycle symptoms experienced between World Class DH (n=7) and World Class XCO (n=15). Confidence intervals are excluded due to small sample size.*

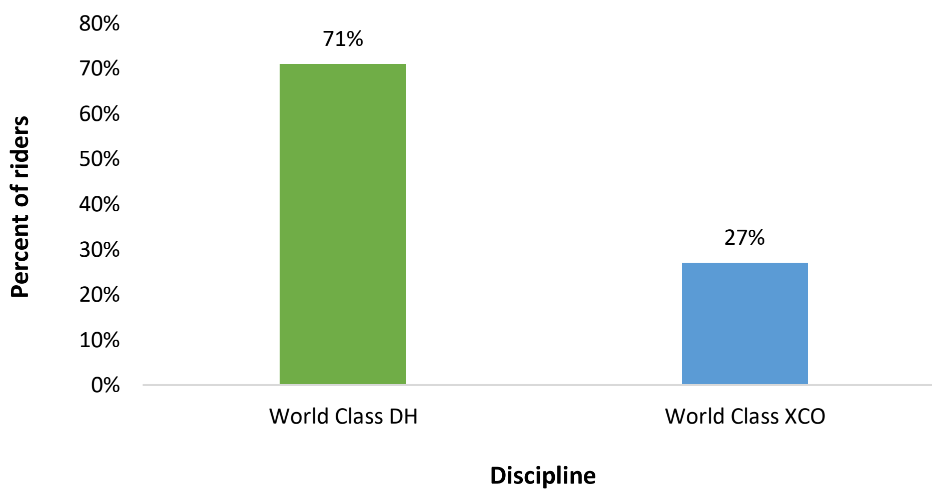

Figure 17. *Prevalence of riders that missed or modified their training in the last six months due to menstrual cycle symptoms. A comparison between World Class DH (n=7) and World Class XCO (n=15). Confidence intervals are excluded due to small sample size.*

5. Discussion

Female specific health issues have the potential to impact negatively on both performance and long-term health in World Cup Mountain biking. By better understanding and educating on these specific issues that face female riders, not only can health be protected, but there is also an opportunity to improve performance by working *with* a woman's physiology. This chapter will include a full discussion, evaluation, and interpretation of the most important findings of this research as they relate to menstrual disturbances and general health, hormonal contraceptive use, menstrual cycle characteristics and the differences between disciplines cross-country and downhill.

5.1. MENSTRUAL DISTURBANCES AND GENERAL HEALTH

5.1.1. Menstrual disturbances

Due to the self-report method of this research, menstrual disturbances in this study refer to amenorrhea and oligomenorrhea only. In this research, 12% of riders had experienced delayed menarche which is lower than what has been previously reported in the literature on elite athletes (15% to 60%) (Goodwin et al., 2014; Heather et al., 2021; Solli et al., 2020). Despite most riders experiencing their first period at a healthy age, menstrual disturbances had subsequently been diagnosed in 25% of riders, which included present or historical amenorrhea or oligomenorrhea. This is more than double what was reported in recent research by Heather et al. (2021) on elite New Zealand athletes, where 12% had been diagnosed with menstrual disturbances. When asked about menstrual cycle regularity in the preceding 12 months, a total of 30% of non-hormonal contraceptive users fit the criteria for present undiagnosed menstrual disturbances. Further, a total of 58% of riders experienced menstrual disturbances either currently or historically, whether that was diagnosed or not.

This is similar to findings by Heather et al. (2021) who reported 50% of riders not on hormonal contraceptives with present or historical menstrual disturbances. Due to self-reporting of historical menstrual disturbances without a timeframe, recall bias is likely to be high in these results.

It is noteworthy, that undiagnosed menstrual disturbances in this study were more than double that of diagnosed menstrual disturbances; 25% compared to 58%. This is consistent with findings from Heather et al. (2021) who reported much higher undiagnosed menstrual disturbances (50%) than diagnosed (12%). The higher prevalence of undiagnosed menstrual disturbances compared to diagnosed menstrual disturbances is likely to be impacted by recall bias and lack of education and understanding about the impact of hormonal contraceptives on a natural cycle. In support of this, Larsen, Morris, Quinn, Osborne, and Minahan (2020) surveyed 189 elite Australian athletes and reported low knowledge scores on questions relating to the menstrual cycle and oral contraceptives. However, being an individual athlete or an athlete already on hormonal contraceptives was associated with significantly higher knowledge scores (Larsen et al., 2020). The gap between diagnosed and undiagnosed menstrual disturbances seen in this study is still noteworthy as could indicate some women are experiencing health problems but going unnoticed without getting the support they need.

As expected, the total prevalence of menstrual disturbances in World Cup mountain bikers was higher than what is seen in the general population: 58% compared to < 30% (Burrows & Bird, 2000; Goodwin et al., 2014; Kwak et al., 2019). This is consistent with research in other sports showing a higher prevalence of menstrual disturbances in elite athletes than non-athletes or the general population (Goodwin et al., 2014; Martin et al.,

2018; Melin et al., 2015; Meng et al., 2020; Oxfeldt et al., 2020; Pollock et al., 2010; Quah et al., 2009).

There were no differences in menstrual disturbances according to age, discipline, or training volume. Heather et al. (2021) came to the same conclusion regarding menstrual disturbances with age and training volume. However, Oxfeldt et al. (2020) reported an association between amenorrhea and higher cardiovascular training volumes in elite endurance athletes. Although the research is conflicting, one theory for why there were no observed differences in this research is that all athletes were training and competing at the highest level internationally and under a huge amount of psychological and physiological stress. Training volumes were high for all, and this is regardless of age and discipline.

5.1.2. RED-S and the female athlete triad

The relationships between components of the female athlete triad and RED-S, including disordered eating, menstrual disturbances and low bone density, are well recognized in the research to date (Castanier et al., 2021; Cobb et al., 2003; De Souza et al., 2010; Melin et al., 2015; Meng et al., 2020; Mountjoy et al., 2014; Oxfeldt et al., 2020; Torstveit & Sundgot-Borgen, 2005b; Williams et al., 2017) and reiterated in this study. Specifically, the prevalence of amenorrhea was significantly higher in those who engaged in disordered eating practices such as purging/vomiting, training on rest days or very restrictive dieting. This is consistent with findings from Cobb et al. (2003) who reported collegiate and regional level distance runners with higher scores on the Eating Disorder Inventory were 4 times more likely to have amenorrhea or oligomenorrhea. Although Cobb et al. (2003) did not see a relationship between total energy intake and menstrual disturbances, they speculate that women with eating disorders have different eating patterns such as fasting and bingeing which alters metabolism, hormone levels and ultimately menstruation despite

not being in an overall energy deficit. In addition, Fahrenholtz et al. (2018) suggest that despite similar 24-hour energy availability, endurance athletes with menstrual disturbances spent more time in a catabolic state than endurance athletes with a eumenorrheic cycle. Within-day energy deficiency is therefore another important consideration for menstrual health (Fahrenholtz et al., 2018) and is relevant with regards to the high training loads and competition schedules of female mountain bikers competing at World Cups and the World Championships.

Medically diagnosed disordered eating was significantly higher in those who had also been diagnosed with low bone density, RED-S, or the female athlete triad. The prevalence of medically diagnosed RED-S or the female athlete triad were the same as that by Heather et al. (2021) at 9% as well as a similar prevalence of low bone density (2% to 3%). The finding that RED-S and the female athlete triad are associated with higher weekly training volumes in this study is consistent with what is already known in this area. Higher training volumes put these athletes at increased risk of low energy availability, which is one of the underlying causes of RED-S and the female athlete triad (Melin et al., 2015; Meng et al., 2020; Mountjoy et al., 2018). These findings show that elite female mountain bikers are at increased risk of negative health and performance outcomes related to RED-S and the female athlete triad.

5.1.3. Eating disorders

In this study 15% of riders had been medically diagnosed with an eating disorder and 58% of riders had engaged in some form of disordered eating practices. This is much higher than what was seen by Heather et al. (2021) who recorded 4% with medically diagnosed eating disorders and 15% engaged in disordered eating practices. It is a concerning observation that in this particular sport, females appear to have a much higher prevalence of eating disorders and associated unhealthy practices when compared to female athletes in

other sports; both individual and team sports (Heather et al., 2021). The high prevalence of eating disorders in this research could be due to the high percentage of endurance athletes (86%) and the associated high drive for leanness or additional pressure to achieve a lower body weight for performance in endurance sports (Quah et al., 2009; Torstveit & Sundgot-Borgen, 2005b).

Mountain biking is an individual sport and Heather et al. (2021) found that individual sport athletes have significantly higher training loads and higher risk of overall illness when compared to team sport athletes. This could be another factor relating to the higher prevalence of eating disorders and unhealthy practices when compared to research that includes team sport athletes (Heather et al., 2021). Additionally, Quah et al. (2009) found that female athletes competing at the highest level internationally were at greater risk of eating disorders. It is also important to recognise that elite female athletes in any sport are under a huge amount of pressure to achieve a certain body type for appearance reasons, and Heather et al. (2021) found this to be irrespective of age, training volume or performance level. They identified the primary source of this pressure as coming from social media (80%). It is clear that eating disorders and related behaviours are a significant issue for elite female mountain bikers.

5.1.4. Concussion and depression

Regarding injuries, stress fractures were somewhat low compared to other sports. This is most likely due to the rider being exposed to constant vibrations and impacts in mountain biking (Macdermid, Fink, & Stannard, 2014) which stimulates osteogenic bone signalling, improving bone health (McVeigh, Meiring, Cimato, Micklesfield, & Oosthuyse, 2015; Oosthuyse, Bosch, Kariem, & Millen, 2021). In this sense, mountain biking is different to other weight-supported sports such as road cycling and swimming which are associated

with low bone workload and low bone mass (Warden, Edwards, & Willy, 2021). Concussions were high with almost a quarter of the cohort having a previous or current diagnosis. Concussions were significantly higher in downhill riders than cross-country riders which is unsurprising given the differences in disciplines. Further, 17% of riders had been diagnosed with depression or anxiety and this was more likely to be in those who had been diagnosed with concussions. This relationship between concussions and depression was statistically significant and is consistent with findings from previous research.

Several studies have shown an increase in acute depression following concussion in high school and college athletes (Hutchison, Mainwaring, Richards, Comper, & Bisschop, 2009; Kontos, Covassin, Elbin, & Parker, 2012). This could be due to time off from sport, uncertainty around timeframe for return-to-sport, loss of athletic identity and recovery from injury. Additionally, similar areas of the brain are said to be affected in both depression and concussions (e.g., prefrontal, hippocampus, white matter disruption) (Chen, Johnston, Petrides, & Ptito, 2008).

Further, research has shown that athletes with a history of depression are at increased risk of experiencing depression following a concussion with Yang, Peek-Asa, Covassin, and Torner (2015) reporting 4.59 times greater risk. As well as acute depression, research on retired National Football League players showed a dose-response relationship between number of concussions and likelihood of long-term clinical depression (Guskiewicz et al., 2007).

The relationship observed between concussion and depression or anxiety in female mountain bikers is worth further exploration. This is especially important considering the high prevalence of concussions in downhill racing and what is already known about concussions having a higher incidence and recovery time in female athletes compared to male

athletes. These differences are due to sex differences such as biomechanics, biochemistry and anatomy (Rizzone & Ackerman, 2021).

Although there was also a relationship observed between stress fractures and depression or anxiety, this affected less women in this sport with only 5% of riders experiencing stress fractures.

5.1.5. Iron deficiency and anaemia

Iron deficiency or anaemia was reported by over a third of athletes in this study. This is lower than that seen in elite distance runners competing in 2015 London Marathon where 52.5% reported a history of anaemia (Bruinvels et al., 2016). Although menstruation is the most common cause of iron deficiency or anaemia in women, athletes are at increased risk due to iron losses through haematuria, gastrointestinal bleeding, sweating and haemolysis (Bruinvels et al., 2016). Previous research has found that due to increased blood loss, those with heavy menstrual bleeding are more likely to suffer from iron deficiency or anaemia (Bruinvels et al., 2016), however this relationship was not observed in this study.

Exercise modality and intensity play a role in post-exercise inflammation and iron regulation (Sim et al., 2013). Iron deficiency or anaemia could be lower in this study when compared to distance runners due to mechanical trauma of foot strike in running being a major cause of haemolysis (Telford et al., 2003). In addition, Sim et al. (2013) report post-exercise serum iron levels were unchanged in low-intensity cycling but elevated in low-intensity running, high-intensity cycling and high-intensity running. This may indicate reduced haemolysis during low-intensity weight-supported activity. Despite the parallels with cycling, mountain bikers have greater mechanical loading from exposure to vibrations and impacts which require muscle dampening at the bike-body interface (Macdermid et al., 2014).

5.2. HORMONAL CONTRACEPTIVE USE

Hormonal contraceptive use in this study was lower than what has been previously reported in the research with 25% of female world cup mountain bikers reporting current hormonal contraceptive use compared to 33% to 72% of elite athletes in previous studies (Brown et al., 2021; Clarke et al., 2021; Coutinho et al., 2021; Findlay et al., 2020; Heather et al., 2021; Larsen et al., 2020; Martin et al., 2018; Oxfeldt et al., 2020; Solli et al., 2020). A further 25% of riders were former hormonal contraceptive users but 50% had never used them before. Like previous research, the primary reason for hormonal contraceptive use was for contraception with 66% of riders stating this. What's interesting though, is that period manipulation was much lower, 16% in this study compared to 40% to 70% in previous studies (Findlay et al., 2020; Heather et al., 2021; Martin et al., 2018; Oxfeldt et al., 2020). Thirty four percent of riders used hormonal contraceptives for enhanced period regularity. This could indicate the desire to have a more "predictable cycle" (predictable withdrawal bleeds) to have less of an impact on training and racing. However, it could also suggest a lack of knowledge of the effects of hormonal contraceptives on the natural cycle. It was not possible to determine how this survey question response was interpreted by the participant and this is acknowledged as a limitation in the results.

5.2.1. Side effects

There is a growing body of literature on the negative side effects of hormonal contraceptives such as mood disturbance, depression, poorer bone health, greater inflammation and oxidative stress (Armour et al., 2020; Cauci, Buligan, Marangone, & Francescato, 2016; Clarke et al., 2021; Heather et al., 2021; Martin et al., 2018). Additionally, more information is being made available and accessible to athletes (e.g. podcasts on female athlete health) about the benefits of having a natural cycle, both to monitor your own health

but also due to the role of menstrual cycle hormones on adaptation to training and performance in elite sport (Heather et al., 2021). Clarke et al. (2021) report the most common reason given for discontinuing hormonal contraceptive use was due to negative side effects (31%), followed by wanting to take a “natural” approach (16%). Very similar figures were reported by Oxfeldt et al. (2020) for reasons for discontinuing use of hormonal contraceptives: negative side effects (41%) and wanting to avoid exogenous hormones (15%).

It is unknown whether the lower numbers of women taking hormonal contraceptives in this study are for reasons specific to the sport of mountain biking or a result of increased knowledge in this area and a wider shift in attitudes around menstruation. In support of this theory, when asked of their beliefs about the impact of the menstrual cycle on performance, only about a third (37%) of riders believed their performance was decreased when they had their period. This was about the same as that reported in recent research by Heather et al. (2021) (36%), but was much lower than what was reported by Bruinvels et al. (2016) (55%) and Armour et al. (2020) (56%). Not only this, but 12% of riders believed that they performed better when they had their period whereas, Heather et al. (2021) reported only 4% of athletes held this same belief. If fewer women are viewing their period as a negative, or in fact more women view their period as performance enhancing, then this could provide an explanation for lower numbers of women using hormonal contraceptives and for lower numbers choosing to skip or alter the timing of their periods around training and particularly races.

Most riders (82%) experienced negative side effects from hormonal contraceptives with the most common being weight gain (40%). A study of 256 Portuguese athletes from 18 different sports reported only 19% of athletes experienced weight gain as a side effect of hormonal contraceptives. Findings from Heather et al. (2021) (24%) and Martin et al. (2018) (7.5%) were also lower. About a third of riders experienced mood disturbance (37%), which

was also higher than findings from Heather et al. (2021) (25%) and Martin et al. (2018) (4%). While it is clear why weight gain would be undesirable in elite sport, mood disturbance can also be quite disruptive as can describe low motivation or increased perceived exertion to training. These are factors associated with hormonal contraceptive use that would be important for coaches to be aware of particularly in elite mountain biking given the higher prevalence of such symptoms.

Another difference seen in this study was that 21% of riders reported a performance deficit as a side effect of their hormonal contraception. This was slightly lower in research by Coutinho et al. (2021) (16%) and negligible in research by Heather et al. (2021) and Martin et al. (2018). Although speculation only, this could suggest there was increased awareness and knowledge in this group of athletes around hormonal contraceptives and their possible side effects. It is reasonable to believe that athletes competing at such a high level would be more in tune with their bodies and sensitive to any changes they notice regarding their health and performance. This does not, however, explain why prevalence of such side effects were higher in this study than previously reported, which brings about the theory that perhaps knowledge, education and attitudes are changing over time. Although it was not asked, these negative side effects could also be reasons for discontinuing use of hormonal contraceptives or switching to a different type.

5.2.2. Types of hormonal contraception

As seen in previous research, the most common type of hormonal contraceptive used was the combined oral contraceptive pill. However, the prevalence was lower than that of other studies at 53% compared to about 65% to 80% (Clarke et al., 2021; Coutinho et al., 2021; Heather et al., 2021; Martin et al., 2018; Solli et al., 2020). The use of IUDs was much higher in this group at 24% compared to 2% to 16% in previous research (Clarke et al., 2021;

Heather et al., 2021; Martin et al., 2018; Solli et al., 2020). It is interesting to see that in this group, overall hormonal contraceptive use was lower, and comparatively fewer women were using oral contraceptive pills, with an increased number of women using IUDs. In support of these findings, a review on IUDs noted that as of 2018, the Canadian Paediatric Society recommends IUDs as the best option of hormonal contraception (Henderson & Scribbans, 2020). They also predicted there to be an increase in the use of IUDs in the years to follow.

Combined oral contraceptive pills provide exogenous estrogen and progestin which down-regulate or suppress endogenous estrogen and progesterone (Henderson & Scribbans, 2020). This circulates throughout the body and can compromise recovery and the ability for adaptation to training due to increased oxidative stress and inflammation (Cauci et al., 2016). Although IUDs contain hormones, it is a much smaller dose of progestin than that in combined oral contraceptive pills and progestin only oral contraceptive pills (Henderson & Scribbans, 2020). They also contain no estrogen and are localised to the uterus. These reasons could make IUDs a better hormonal contraceptive option for high performance athletes due to less consequent effects on the females' physiology (Henderson & Scribbans, 2020). Not only this, but IUDs are effective in reducing menstrual cycle symptoms, in particular heavy menstrual bleeding since it reduces the thickening of the endothelial lining of the uterus (Krishnamoorthy & Verma, 2017). Perhaps this information is reaching the riders and influencing decisions on hormonal contraceptive choices.

5.3. MENSTRUAL CYCLE CHARACTERISTICS

5.3.1. Symptoms and characteristics

Hormonal contraceptive users were able to answer questions relating to their menstrual cycle symptoms and therefore included in the analysis of menstrual cycle

characteristics, as was done in research by Heather et al. (2021). This allowed for women to report their experience with their menstrual cycle, and its impact on their quality of life, regardless of hormonal contraceptive use status. While this added value by allowing for comparisons to previous research, synthetic hormone side effects were a compounding factor in this analysis. While naturally menstruating women present with symptoms of biphasic hormone fluctuations, those on hormonal contraceptives were presenting with symptoms relating to reproductive hormone suppression and synthetic hormone withdrawal. This was also relevant regarding hormonal contraceptive users being included in the analysis for heavy menstrual bleeding and the impact of the menstrual cycle on training and racing. It would be worthwhile further analysing these findings as they relate to only naturally cycling women, however this was beyond the scope of this research project.

Overall, the findings on menstrual cycle symptoms were consistent with previous research. The majority of riders experienced negative or bothersome menstrual cycle symptoms; 89% in this study compared to 77% to 93% in previous studies (Armour et al., 2020; Findlay et al., 2020; Heather et al., 2021; Martin et al., 2018; Oxfeldt et al., 2020; Solli et al., 2020). The highest reported symptoms of pelvic pain (67%), low back pain (53%) and increased fatigue (49%) were all within the range of what has been reported in previous research. Other common symptoms included headaches (37%), disrupted sleep (24%), pain in thighs (20%) and nausea or vomiting (16%). About a third of riders (32%) reported self-medicating during their periods to help with pain, which was similar to findings from Heather et al. (2021) who reported 27% using pain relief most of the time and 6% all of the time. In addition, 29% of riders fit the criteria for heavy menstrual bleeding. This figure is consistent with previous research, showing that heavy menstrual bleeding affects about a third of elite athletes (Armour et al., 2020; Bruinvels et al., 2016; Findlay et al., 2020; Heather et al., 2021).

The criteria used in this research to determine heavy menstrual bleeding was self-reported and included questions relating to the frequency of changing sanitary products, self-perceived menstrual blood loss and quality of life. Although this was the criteria used in recent research by Heather et al. (2021) and Bruinvels et al. (2016), this method is subjective and may have resulted in false positives. Further, Magnay, O'Brien, Gerlinger, and Seitz (2018) suggest that it is not possible to determine menstrual blood loss based on the number of sanitary items used. This is due to the brand and absorbency of products not being taken into account, as well as the many other variables that can influence the frequency of these being changed such as rate and composition of menstrual flow, physical activity, individual anatomy and personal hygiene practices (Magnay et al., 2018).

Given the number of symptoms experienced and prevalence of self-reported heavy menstrual bleeding, it is no surprise that about a third (38%) of riders had either missed or modified their training due to their menstrual cycle. Although, this was only done 1 to 5 times in the last six months. For these riders that had missed or modified their training this was specifically due to fatigue (69%), severe pain or cramps (66%), lack of motivation (55%) or low mood (41%). Research by Armour et al. (2020) also reported fatigue and energy levels (71%) as the most commonly reported reason why athletes missed or modified training. When it came to race day, only 8% of riders had missed a race in the last Olympic cycle (four years) due to their menstrual cycle. Findings from Heather et al. (2021) showed even fewer athletes altered or missed training (14%), and no athletes had missed a race or competition in the last four years. While some female mountain bikers may alter their training due to their menstrual cycle, they are very unlikely to miss a race. There is agreement from Brown et al. (2021) that menstrual cycle symptoms are more disruptive to training than competition. It is clear that when it comes to elite athletes, psychology can override physiology when needed.

5.3.2. Tracking the cycle and barriers to communication

Most riders in this study tracked their menstrual cycle (79%). This is higher than what was reported in research by Heather et al. (2021) (54%). This could suggest that these athletes are more informed and aware about the importance of the menstrual cycle regarding their health and sports performance. It could also show advancements in methods used to track the menstrual cycle, making this easier and more accessible for athletes. The most common method used in this study was a smart phone App (72%) whereas Heather et al. (2021) reported most the common methods as computer software (68%) and a paper or electronic diary (21%). The findings showed that some women still tracked their cycle despite being on hormonal contraceptives. Further analysis would be required to determine the number of women tracking their cycle who were naturally cycling and those that were on hormonal contraceptives. In addition, further questioning was not done on this regarding what these women were specifically tracking and reasons for doing so. This would be worth further exploration in future research.

Sixty five percent of riders said that they do discuss their menstrual cycle with their coach and 74% said they do not experience any barriers to communication on this topic. This is similar to findings from Heather et al. (2021), who report 80% of athletes experienced no barriers to communication. In contrast, Armour et al. (2020) reported that most athletes in their study did not discuss their menstrual cycle with their coach (76%). Main reasons for not discussing were either because they were male, didn’t think they would care or understand, were embarrassed, or didn’t feel that they needed to discuss it. Regarding the 26% of riders in the current research that did experience barriers to communication, these perceived barriers, or reasons for not openly discussing their menstrual cycle included male coaches (95%), the stigma of the topic (74%), the gender of staff (63%) and lack of staff knowledge

(53%). These findings are very similar to those of Armour et al. (2020) and Heather et al. (2021): male coaches (90-95%), the stigma of the topic (64-74%), the gender of staff (63%) and lack of staff knowledge (51-53%). Additionally, Brown et al. (2021) report that previous experiences and perceptions of male awkwardness and lack of knowledge contribute to female athletes feeling uncomfortable discussing their menstrual cycle with their male coaches.

Although it is promising to see higher numbers of female riders in this study feeling comfortable talking to their male coaches about their menstrual cycle, for the women that do not engage in these conversations it appears that the barriers to this remain the same as reported in previous research. In addition, given the majority of coaches in elite sport are male, Armour et al. (2020) suggest that low rates of athletes and coaches altering their training due to menstrual cycle symptoms could be due to female athletes being uncomfortable talking to their coaches about these symptoms. As a result, coaches could be unaware of the way in which an athletes' menstrual cycle is negatively impacting them. More work is needed to continue to break down the stigma associated with the menstrual cycle, especially regarding the female athlete and male coach interactions.

5.4. CROSS-COUNTRY VERSUS DOWNHILL

This section discusses the results relating to World Class XCO and World Class DH: the senior level riders who had placed in the top 10 in a World Cup or World Championship race in the preceding two years at the time of taking the survey. These represent the highest-level athletes taking the survey and are also some of the best riders in the world. Although none of the findings comparing these two groups were significant due to the small sample size, this comparison highlighted health issues specific to each discipline.

Although the overall prevalence of present or historical menstrual disturbances were about the same between World Class XCO (67%) and World Class DH (71%) riders, World Class DH riders appeared to have a higher prevalence of oligomenorrhea than World Class XCO riders, at 71% and 60% respectively. However, World Class XCO riders appeared to have a higher prevalence of the most severe type of menstrual disturbance, amenorrhea, 40% in World Class XCO riders and 29% in World Class DH riders. The open-ended time frame of survey questions relating to menstrual disturbances may have led to an increase in recall bias and impacted on these findings.

A key finding in this sub-group analysis is that only World Class XCO riders had been medically diagnosed with eating disorders (20%) or the female athlete triad or RED-S (13%), but this did not affect any of the World Class DH riders studied. In addition, World Class XCO riders reported higher weekly training volumes during the out of competition phase. Given the different physiological demands of each discipline, World Class XCO riders fall into the category of being endurance athletes and having a high drive for leanness. This is due to the duration of cross-country being much longer and having to work against gravity for the majority of race duration on the uphill. It is already well documented in the literature that athletes in endurance and “lean” sports are more likely to be under additional pressure to achieve and maintain a lower body weight and have higher training volumes (Quah et al., 2009; Torstveit & Sundgot-Borgen, 2005b). This can result in a higher prevalence of eating disorders, menstrual disturbances, low energy availability and RED-S or the female athlete triad (Cobb et al., 2003; Goodwin et al., 2014; Melin et al., 2015; Meng et al., 2020; Quah et al., 2009). The findings from World Class XCO riders are consistent with this and suggest that targeted education and management tools for issues surrounding eating disorders, low energy availability and RED-S are even more important in this discipline of mountain biking.

As reported in the findings including all riders, concussions were much higher in World Class DH riders compared to World Class XCO riders with over half of World Class DH riders having a diagnosed concussion (57% versus 13%). This is not surprising given the high speeds and extreme courses in downhill. Medically diagnosed depression and anxiety were also higher in World Class DH riders (29%) than World Class XCO (13%) riders. The differences in depression and anxiety with discipline were also seen in the data including all riders. The possible mechanisms of the relationship between concussions and depression or anxiety have already been discussed in **Chapter 5.1.4 Concussion and depression.**

When comparing World Class XCO and World Class DH results to findings from all riders in each discipline (regardless of age or rank), there were some key similarities and differences worth highlighting. Menstrual disturbances and hormonal contraceptive use was similar between World Class XCO and all cross-country riders, as well as World Class DH and all downhill riders. Depression or anxiety was prevalent in 9% of all downhill riders, but this was much more pronounced in the World Class DH group at 29%. In cross-country, iron deficiency or anaemia was much higher in the all riders group than the World Class XCO group; 40% compared to 20%. In all group data, there were no differences between disciplines regarding heavy menstrual bleeding and menstrual cycle symptoms. However, when comparing World Class DH and World Class XCO, these were more prevalent in the World Class DH group. As such, the World Class DH group experienced more disruption to their training due to their menstrual cycle than what was seen all downhill riders; 71% compared to 54%. In contrast to World Class DH riders, World Class XCO riders experienced less disruption to training than that of all cross-country riders; 27% compared to 35%. When it comes to the impact of the menstrual cycle on the highest-level riders, downhill riders in this study are more impacted than cross-country riders.

The analysis of menstrual cycle symptoms in World Class DH riders and World Class XCO riders included all women, regardless of hormonal contraceptive use as was done by Heather et al. (2021). Women on hormonal contraceptives were therefore reporting symptoms and period characteristics that were influenced by synthetic hormones including withdrawal bleeds. As with data on all riders, an analysis of menstrual cycle symptoms and period characteristics such as heavy menstrual bleeding, is worth further investigation in only naturally cycling World Class DH riders and World Class XCO riders.

6. Conclusions

This chapter will cover firstly, section **6.1. CONCLUSIONS** which includes answering the research questions and summarising other main findings of interest. Secondly, a discussion of the limitations (**6.2. LIMITATIONS**) and finally, practical advice and future directions of research (**6.3. RECOMMENDATIONS**).

6.1. CONCLUSIONS

In conclusion, this research confirmed that elite World Cup Mountain bikers experience menstrual disturbances like that of elite athletes in other sports and at greater rates than the general population. This was to be expected given athletes are at increased risk of low energy availability which underpins menstrual disturbances. This is important sport-specific knowledge, given the long-term health consequences of menstrual disturbances and energy deficiency. Athletes in this study also experienced menstrual cycle symptoms like women in other sports and the general population but at this level, almost no women missed a race because of such symptoms. There were no significant differences observed between cross-country and downhill riders, but this finding was limited due to the small number of downhill riders.

To answer the research questions, outlined in **Chapter 2.5. Summary and research questions**:

1. What is the prevalence of menstrual disturbances in female World Cup Mountain bikers?

   The prevalence of present or historical menstrual disturbances was 58%.

2. What is the prevalence and reasons for use of hormonal contraceptives in female World Cup Mountain bikers?

The prevalence of current hormonal contraceptive use was 25% which is lower than in previous research, with less women using for the purpose of period manipulation. The main reasons for use included contraception (66%), to enhance period regularity (34%) and to reduce period pain (24%).

3. What are the menstrual cycle symptoms and period characteristics of riders and what is the perceived impact of these on their training and racing?

   Most riders experienced menstrual cycle symptoms which were highly individualised and varied. The most common were pelvic pain (67%), low back pain (53%) and increased fatigue (49%). About a third of riders experienced heavy menstrual bleeding. Despite these symptoms, riders had mixed responses as to the impact of this on their performance.

4. What impact does discipline (cross-country or downhill) have on menstrual health in World Cup Mountain biking?

   Discipline had no impact on menstrual disturbances, hormonal contraceptive use or menstrual cycle symptomology. Although not statistically significant, diagnosed amenorrhea was higher in World Class XCO riders (40%) than in World Class DH riders (29%). Diagnosed eating disorders, the female athlete triad and RED-S were only seen in World Class XCO riders but not in World Class DH riders.

Although not specific to the research questions, there were some other interesting findings to emerge from this research. Firstly, eating disorders and disordered eating practices were relatively high in World Cup Mountain biking. In the World Class athletes, eating disorders and RED-S or the female athlete triad pertained only to cross-country riders (although this finding was not statistically significant due to the small sample size in this sub-group analysis). The prevalence of RED-S or the female athlete triad in World Class XCO riders

was not surprising given these riders also reported higher weekly training volumes than World Class DH riders, out of competition phase. Secondly, concussions and associated depression or anxiety are the most prevalent health issue facing downhill riders. Finally, this group of athletes appeared to have some differences to what had been reported in previous research which could suggest an informed group of women who are aware of the impact of their menstrual cycle on their health and performance. These included: fewer women using hormonal contraceptives, more women using IUDs, less women viewing their period in a negative light, more women tracking their menstrual cycle and more women discussing their menstrual cycle with their coach. Despite what appears to be increased knowledge and awareness around the menstrual cycle for these riders, the stigma associated with the menstrual cycle and male coaches is still a barrier to communication for some women.

6.2. LIMITATIONS

Several potential limitations are acknowledged in this research project. The survey distribution method used meant it was not possible to determine the reach and therefore whether the participants are representative of the target population. Additionally, this research was open to self-selection bias, in which women may have taken part in this research because they were already interested and informed on this topic. This could be one reason why the results suggest these riders have increased awareness about their menstrual health. Due to the timing of the data collection phase, some athletes may have completed their responses prior to World Championship and Olympic selection for their country. The numbers of those competing in the 2021 World Championships and/or Tokyo Olympic Games are likely to be underreported. The small sample size, especially regarding the sub-group analysis of World Class riders, reduced the power of this study and increased margin of error.

This limits the statistical inferences and conclusions that can be made. However, as McKay et al. (2022) highlight, participation of World Class athletes in research is such a rarity that the findings are particularly valuable.

Due to the retrospective nature of some of the questions in the survey and the inclusion of historical health questions over the athlete's entire career to this date, this research is likely to be impacted by recall bias, in which accuracy of data is dependent on memory. Further, the prevalence of menstrual disturbances could seem quite high due to including present and historical menstrual disturbances, with an open-ended time frame. However, it was important to include historical data as this is indicative of long-term energy availability and could be linked to other factors such as poor bone health. Present menstrual disturbances are more reflective of recent energy availability. Collecting information on not only their current menstrual health but also their historical menstrual health was important to better understand the female athlete experience and journey to becoming an elite level athlete. The self-reported data of undiagnosed menstrual disturbances could have been impacted by the level of education, knowledge and understanding of the menstrual cycle including how hormonal contraceptives affect the natural cycle. This may have resulted in over-reporting of the true incidence of undiagnosed menstrual disturbances.

When asked about previous hormonal contraceptive use, there was no further questioning on when use stopped. It was then not possible to determine whether athletes had used hormonal contraceptives in the preceding 12 months, and this may have impacted on results relating to menstrual cycle regularity and present menstrual disturbances. This is because it may take three months or more for regular cycles to return after the cessation of hormonal contraceptive use.

The criteria used to determine heavy menstrual bleeding was highly subjective and may have resulted in false positives. While this is acknowledged as a limitation, this research was interested in reporting the female athlete experience of her menstrual cycle. Menstrual history and self-determined heavy menstrual bleeding were viewed as very important due to the impact this has had and may continue to have on her throughout her athletic career. Further, there was no specific time frame given when asked out characteristics associated with heavy menstrual bleeding. As such, it was not possible to determine when or for how long an athlete was experiencing this.

It was quite difficult to compare these findings against other studies due to the inconsistency in menstrual health research procedures. For example, in previous research there is a lot of variation regarding what is and isn't included, measures used, how menstrual disturbances are defined and the inclusion or exclusion of women on hormonal contraceptives. As well as this, survey methods commonly used in menstrual health research are open to interpretation of questions, another limitation of this study. Finally, as a cross-sectional study, this research collected data to represent a point in time, therefore, conclusions were unable to be drawn on causality.

6.3. RECOMMENDATIONS

The menstrual cycle should be considered as another aspect of female athlete health and sports performance. Education and increased knowledge are required by athletes, coaches and support staff on the menstrual cycle and hormonal contraceptive use (Armour et al., 2020; Clarke et al., 2021; Elliott-Sale et al., 2021; Heather et al., 2021; Larsen et al., 2020). This is one of the first steps to helping reduce the stigma associated with the menstrual cycle and breaking down barriers to communication, especially with male coaches (Brown et

al., 2021; Clarke et al., 2021). Support staff should be aware of the highly individualised way in which the menstrual cycle affects female athletes.

It is recommended that athletes track their menstrual cycle as this is an easy way to gather information relating to their specific symptoms and to monitor their menstrual health (Armour et al., 2020; Heather et al., 2021). More education is required for athletes and support staff about eating disorders and RED-S, particularly in elite cross-country mountain biking. Screening and monitoring strategies could be required to ensure athletes impacted by this get the support they need.

There is still a gender gap in sport science research with women being under-represented in the literature (Bruinvels et al., 2017; Elliott-Sale et al., 2021). Although there has been an increase in recent years, more research is still needed on the impact of the menstrual cycle and hormonal contraceptive use on sports performance (Clarke et al., 2021; Elliott-Sale et al., 2021). This should include looking at different types of hormonal contraceptive methods. In addition, concussions and depression or anxiety in female downhill mountain bikers is worth further exploration. More research is warranted on eating disorders and RED-S in elite cross-country mountain bikers. These future directions of research would continue to inform and support elite female athletes to protect their long-term health and maximise performance in elite sport.

References

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

Arriel, R. A., Souza, H. L. R., Sasaki, J. E., & Marocolo, M. (2022). Current perspectives of cross-country mountain biking: physiological and mechanical aspects, evolution of bikes, accidents and injuries. *International Journal of Environmental Research and Public Health, 19*(19), 12552.

Berry, M. J., Koves, T. R., & Benedetto, J. J. (2000). The influence of speed, grade and mass during simulated off road bicycling. *Applied Ergonomics, 31*(5), 531-536. doi:10.1016/S0003-6870(00)00022-3

Brown, J. B. (2011). Types of ovarian activity in women and their significance: the continuum (a reinterpretation of early findings). *Human Reproduction Update, 17*(2), 141-158. doi:10.1093/humupd/dmq040

Brown, N., Knight, C. J., & Forrest, L. J. (2021). Elite female athletes' experiences and perceptions of the menstrual cycle on training and sport performance. *Scandinavian Journal of Medicine & Science in Sports, 31*(1), 52-69.

Bruinvels, G., Burden, R., Brown, N., Richards, T., & Pedlar, C. (2016). The prevalence and impact of heavy menstrual bleeding (menorrhagia) in elite and non-elite athletes. *PLoS ONE, 11*(2), 1-8. doi:10.1371/journal.pone.0149881

Bruinvels, G., Burden, R. J., McGregor, A. J., Ackerman, K. E., Dooley, M., Richards, T., & Pedlar, C. (2017). Sport, exercise and the menstrual cycle: where is the research? *British Journal of Sports Medicine, 51*(6), 487.

Burrows, M., & Bird, S. (2000). The physiology of the highly trained female endurance runner. *Sports Medicine, 30*(4), 281-300.

Canelón, S. P., & Boland, M. R. (2020). A systematic literature review of factors affecting the timing of menarche: The potential for climate change to impact women's health. *International Journal of Environmental Research and Public Health, 17*(5), 1703.

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

Cauci, S., Buligan, C., Marangone, M., & Francescato, M. P. (2016). Oxidative stress in female athletes using combined oral contraceptives. *Sports Medicine - Open, 2*(1). doi:10.1186/s40798-016-0064-x

Cea-Soriano, L., García Rodríguez, L. A., MacHlitt, A., & Wallander, M. A. (2014). Use of prescription contraceptive methods in the UK general population: A primary care study. *BJOG: An International Journal of Obstetrics and Gynaecology, 121*(1), 53-61-61. doi:10.1111/1471-0528.12465

Chen, J.-K., Johnston, K. M., Petrides, M., & Ptito, A. (2008). Neural substrates of symptoms of depression following concussion in male athletes with persisting postconcussion symptoms. *Archives of General Psychiatry, 65*(1), 81-89. doi:10.1001/archgenpsychiatry.2007.8

Chidley, J. B., MacGregor, A. L., Martin, C., Arthur, C. A., & Macdonald, J. H. (2015). Characteristics explaining performance in downhill mountain biking. *International Journal of Sports Physiology & Performance, 10*(2), 183-190.

Clarke, A., Bruinvels, G., Julian, R., Inge, P., Pedlar, C., & Govus, A. (2021). Hormonal contraceptive use in football codes in Australia. *Frontiers in Sports and Active Living, 3*. doi:10.3389/fspor.2021.634866

Cobb, K. L., Bachrach, L. K., Greendale, G., Marcus, R., Neer, R. M., Nieves, J., . . . Kelsey, J. L. (2003). Disordered eating, menstrual irregularity, and bone mineral density in female runners. *Medicine & Science in Sports & Exercise, 35*(5), 711-719. doi:10.1249/01.MSS.0000064935.68277.E7

Coutinho, F. M., Rebelo-Marques, A., Andrade, R., Espregueira-Mendes, J., Bombas, T., & Moura, P. (2021). Menstrual pattern and contraceptive choices of Portuguese athletes. *The European Journal of Contraception and Reproductive Health Care, 26*(3), 240-245. doi:10.1080/13625187.2021.1879780

De Souza, M. J. (2003). Menstrual disturbances in athletes: A focus on luteal phase defects. *Medicine and Science in Sports and Exercise, 35*, 1553-1563. doi:10.1249/01.MSS.0000084530.31478.DF

De Souza, M. J., Toombs, R. J., Scheid, J. L., Williams, N. I., O'Donnell, E., & West, S. L. (2010). High prevalence of subtle and severe menstrual disturbances in exercising women: Confirmation using daily hormone measures. *Human Reproduction, 25*(2), 491-503-503. doi:10.1093/humrep/dep411

De Souza, M. J., & Williams, N. I. (2004). Physiological aspects and clinical sequelae of energy deficiency and hypoestrogenism in exercising women. *Human Reproduction Update, 10*(5), 433-448. doi:10.1093/humupd/dmh033

Elliott-Sale, K. J., Minahan, C. L., de Jonge, X. A. K. J., Ackerman, K. E., Sipilä, S., Constantini, N. W., . . . Hackney, A. C. (2021). Methodological considerations for studies in sport and exercise science with women as participants: A working guide for standards of practice for research on women. *Sports Medicine, 51*(5), 843-861. doi:10.1007/s40279-021-01435-8

Fahrenholtz, I. L., Sjödin, A., Melin, A. K., Tornberg, Å. B., Benardot, D., Skouby, S., . . . Sundgot-Borgen, J. K. (2018). Within-day energy deficiency and reproductive function in female endurance athletes. *Scandinavian Journal of Medicine and Science in Sports, 28*(3), 1139-1146-1146. doi:10.1111/sms.13030

Findlay, R. J., MacRae, E. H. R., Easton, C., Forrest, L. J., & Whyte, I. Y. (2020). How the menstrual cycle and menstruation affect sporting performance: Experiences and perceptions of elite female rugby players. *British Journal of Sports Medicine, 54*(18), 1108-1113-1113. doi:10.1136/bjsports-2019-101486

Garner, D. (2004). *Eating disorder inventory-3 (EDI-3) Professional Manual: Psychological Assessment Resources* (Vol. 35). Lutz, FL.

Goodwin, Y., Monyeki, M. A., Boit, M. K., De Ridder, J. H., Toriola, A. L., Mwangi, F. M., . . . Mwihaki, M. G. (2014). Profile of the female athlete triad among elite Kenyan endurance athletes and non-athletes. *African Journal for Physical, Health Education, Recreation & Dance, 20*(2.2), 610-625.

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

Guskiewicz, K. M., Matthews, A., Mihalik, J. R., Marshall, S. W., Bailes, J., McCrea, M., . . . Cantu, R. C. (2007). Recurrent concussion and risk of depression in retired professional football players. *Medicine and Science in Sports and Exercise, 39*(6), 903-909-909. doi:10.1249/mss.0b013e3180383da5

Haakonssen, E. C., Martin, D. T., Jenkins, D. G., & Burke, L. M. (2015). Race weight: Perceptions of elite female road cyclists. *International journal of sports physiology and performance, 10*(3), 311-317. doi:10.1123/ijspp.2014-0070

Hawkins, S. M., & Matzuk, M. M. (2008). The menstrual cycle: basic biology. *Annals of the New York Academy of Sciences, 1135*, 10-18. doi:10.1196/annals.1429.018

Heather, A., Thorpe, H., Ogilvie, M., Sims, S., Beable, S., Milsom, S., . . . Hamilton, B. (2021). Biological and socio-cultural factors have the potential to Influence the health and performance of elite female athletes: A cross sectional survey of 219 elite female athletes in Aotearoa New Zealand. *Frontiers in Sports and Active Living, 3*. doi:10.3389/fspor.2021.601420

Henderson, Z., & Scribbans, T. (2020). Intrauterine contraception and athletic performance: Where is the data? *The Health & Fitness Journal of Canada, 13*(2), 37-45.

Huhmann, K. (2020). Menses requires energy: A review of how disordered eating, excessive exercise, and high stress lead to menstrual irregularities. *Clinical Therapeutics, 42*(3), 401-407-407. doi:10.1016/j.clinthera.2020.01.016

Hurst, H., & Atkins, S. (2006). Power output of field-based downhill mountain biking. *Journal Of Sports Sciences, 24*(10), 1047-1053.

Hutchison, M., Mainwaring, L. M., Richards, D. W., Comper, P., & Bisschop, S. M. (2009). Differential emotional responses of varsity athletes to concussion and musculoskeletal injuries. *Clinical Journal of Sport Medicine, 19*(1), 13-19-19. doi:10.1097/JSM.0b013e318190ba06

Impellizzeri, F., M., & Marcora, S. (2007). The physiology of mountain biking. *Sports Medicine*(1), 59.

Kontos, A. P., Covassin, T., Elbin, R. J., & Parker, T. (2012). Depression and neurocognitive performance after concussion among male and female high school and collegiate athletes. *Archives of Physical Medicine and Rehabilitation, 93*(10), 1751-1756. doi:10.1016/j.apmr.2012.03.032

Krishnamoorthy, K., & Verma, U. (2017). *Intrauterine devices (IUD): Clinical aspects, side effects and potential complications* (Vol. 120): Nova Science Publishers, Inc.

Kwak, Y., Kim, Y., & Baek, K. A. (2019). Prevalence of irregular menstruation according to socioeconomic status: A population-based nationwide cross-sectional study. *PLoS ONE, 14*(3), 1-12. doi:10.1371/journal.pone.0214071

Larsen, B., Morris, K., Quinn, K., Osborne, M., & Minahan, C. (2020). Practice does not make perfect: A brief view of athletes' knowledge on the menstrual cycle and oral contraceptives. *Journal of Science and Medicine in Sport*. doi:10.1016/j.jsams.2020.02.003

Macdermid, P., & Stannard, S. (2012). Mechanical work and physiological responses to simulated cross-country mountain bike racing. *Journal Of Sports Sciences, 30*(14), 1491-1501.

Macdermid, P. W., Fink, P. W., & Stannard, S. R. (2014). Transference of 3D accelerations during cross-country mountain biking. *Journal Of Biomechanics, 47*(8), 1829-1837. doi:10.1016/j.jbiomech.2014.03.024

Magnay, J. L., O'Brien, S., Gerlinger, C., & Seitz, C. (2018). A systematic review of methods to measure menstrual blood loss. *BMC Women's Health, 18*(1). doi:10.1186/s12905-018-0627-8

Martin, D., Sale, C., Cooper, S. B., & Elliott-Sale, K. J. (2018). Period prevalence and perceived side effects of hormonal contraceptive use and the menstrual cycle in elite athletes. *International Journal of Sports Physiology & Performance, 13*(7), 926-932.

Maruo, T., Katayama, K., Barnea, E., & Mochizuki, M. (1992). A role for thyroid hormone in the induction of ovulation and corpus luteum function. *Hormone Research in Paediatrics, 37*(Suppl. 1), 12-18.

McKay, A. K. A., Stellingwerff, T., Smith, E. S., Martin, D. T., Mujika, I., Goosey-Tolfrey, V. L., . . . Burke, L. M. (2022). Defining training and performance caliber: A participant classification framework. *International journal of sports physiology and performance, 17*(2), 317-331. doi:10.1123/ijspp.2021-0451

McNulty, K. L., Elliott-Sale, K. J., Dolan, E., Swinton, P. A., Ansdell, P., Goodall, S., . . . Hicks, K. M. (2020). The effects of menstrual cycle phase on exercise performance in eumenorrheic women: A systematic review and meta-analysis. *Sports Medicine, 50*(10), 1813-1827. doi:10.1007/s40279-020-01319-3

McVeigh, J. A., Meiring, R., Cimato, A., Micklesfield, L. K., & Oosthuyse, T. (2015). Radial bone size and strength indices in male road cyclists, mountain bikers and controls. *European Journal of Sport Science, 15*(4), 332-340.

Melin, A., Tornberg, Å. B., Skouby, S., Faber, J., Ritz, C., Sjödin, A., & Sundgot-Borgen, J. (2014). The LEAF questionnaire: A screening tool for the identification of female athletes at risk for the female athlete triad. *British Journal of Sports Medicine, 48*(7), 540-545. doi:10.1136/bjsports-2013-093240

Melin, A., Tornberg, Å. B., Skouby, S., Møller, S. S., Sundgot-Borgen, J., Faber, J., . . . Sjödin, A. (2015). Energy availability and the female athlete triad in elite endurance athletes. *Scandinavian Journal of Medicine & Science in Sports, 25*(5), 610-622.

Meng, K., Qiu, J., Benardot, D., Carr, A., Yi, L., Wang, J., & Liang, Y. (2020). The risk of low energy availability in Chinese elite and recreational female aesthetic sports athletes. *Journal of the International Society of Sports Nutrition, 17*(1), 1-7.

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Ackerman, K. E., Blauwet, C., Constantini, N., . . . Budgett, R. (2018). International Olympic Committee (IOC) consensus statement on Relative Energy Deficiency in Sport (RED-S): 2018 update. *International Journal of Sport Nutrition & Exercise Metabolism, 28*(4), 316-331.

Mountjoy, M., Sundgot-Borgen, J., Burke, L., Carter, S., Constantini, N., Lebrun, C., . . . Ljungqvist, A. (2014). The IOC consensus statement: Beyond the Female Athlete Triad-Relative Energy Deficiency in Sport (RED-S). *Sport & Geneeskunde*(4), 15-28.

Novak, A. R., Bennett, K. J. M., Fransen, J., & Dascombe, B. J. (2018). A multidimensional approach to performance prediction in Olympic distance cross-country mountain bikers. *Journal Of Sports Sciences, 36*(1), 71-78.

Oosthuyse, T., Bosch, A. N., Kariem, N., & Millen, A. M. E. (2021). Mountain bike racing stimulates osteogenic bone signaling and ingesting carbohydrate-protein compared with carbohydrate-only prevents acute recovery bone resorption dominance. *Journal of Strength & Conditioning Research, 35*(2), 292-299.

Oxfeldt, M., Dalgaard, L. B., Jørgensen, A. A., & Hansen, M. (2020). Hormonal contraceptive use, menstrual dysfunctions, and self-reported side effects in elite athletes in

Denmark. *International Journal of Sports Physiology & Performance, 15*(10), 1377-1384.

Pollock, N., Grogan, C., Perry, M., Morrissey, D., Pedlar, C., Cooke, K., & Dimitriou, L. (2010). Bone-mineral density and other features of the female athlete triad in elite endurance runners: A longitudinal and cross-sectional observational study. *International Journal of Sport Nutrition and Exercise Metabolism, 20*(5), 418-426. doi:10.1123/ijsnem.20.5.418

Prior, J. C. (2022). Adaptive, reversible, hypothalamic reproductive suppression: More than functional hypothalamic amenorrhea. *Front Endocrinol (Lausanne), 13*, 893889. doi:10.3389/fendo.2022.893889

Quah, Y. V., Poh, B. K., Noor, M. I., & Ng, L. O. (2009). The female athlete triad among elite Malaysian athletes: Prevalence and associated factors. *Asia Pacific Journal of Clinical Nutrition, 18*(2), 200-208.

Qualtrics. (2021). Qualtrics Survey Software. Provo, Utah, USA. Retrieved from www.qualtrics.com

Redman, L. M., & Loucks, A. B. (2005). Menstrual disorders in athletes. *Sports Medicine, 35*(9), 747-755. doi:10.2165/00007256-200535090-00002

Reed, B. G., & Carr, B. R. (2015). The normal menstrual cycle and the control of ovulation.

Rizzone, K. H., & Ackerman, K. E. (2021). Female athlete and sports-related concussions. *Clinics in Sports Medicine, 40*(1), 133-145. doi:10.1016/j.csm.2020.08.006

RStudio. (2021). RStudio: Integrated Development For R. RStudio, PBC, Boston, MA: RStudio Team. Retrieved from www.rstudio.com

Shufelt, C. L., Torbati, T., & Dutra, E. (2017). Hypothalamic amenorrhea and the long-term health consequences. *Seminars in reproductive medicine, 35*(03), 256-262.

Sim, M., Dawson, B., Landers, G., Swinkels, D. W., Tjalsma, H., Trinder, D., & Peeling, P. (2013). Effect of exercise modality and intensity on post-exercise interleukin-6 and hepcidin levels. *International Journal of Sport Nutrition and Exercise Metabolism, 23*(2), 178-186. doi:10.1123/ijsnem.23.2.178

Solli, G. S., Sandbakk, S. B., Noordhof, D. A., Ihalainen, J. K., & Sandbakk, Ø. (2020). Changes in self-reported physical fitness, performance, and side effects across the phases of the menstrual cycle among competitive endurance athletes. *International Journal of Sports Physiology & Performance, 15*(9), 1324-1333.

Sperlich, B., Achtzehn, S., Buhr, M., Zinner, C., Zelle, S., & Holmberg, H.-C. (2012). Salivary cortisol, heart rate, and blood lactate responses during elite downhill mountain bike racing. *International Journal of Sports Physiology & Performance, 7*(1), 47-52.

Tan, J. O. A., Calitri, R., Bloodworth, A., & McNamee, M. J. (2016). Understanding eating disorders in elite gymnastics: ethical and conceptual challenges. *Clinics in sports medicine, 35*(2), 275-292.

Telford, R. D., Sly, G. J., Bryant, C., Hahn, A. G., Smith, J. A., & Cunningham, R. B. (2003). Footstrike is the major cause of hemolysis during running. *Journal of Applied Physiology, 94*(1), 38-42-42. doi:10.1152/japplphysiol.00631.2001

Torstveit, M. K., & Sundgot-Borgen, J. (2005a). The female athlete triad exists in both elite athletes and controls. *Medicine & Science in Sports & Exercise, 37*(9), 1449-1459.

Torstveit, M. K., & Sundgot-Borgen, J. (2005b). Participation in leanness sports but not training volume is associated with menstrual dysfunction: A national survey of 1276 elite athletes and controls. *British Journal of Sports Medicine, 39*(3), 141-147.

UCI. (2022a). Mercedes Benz UCI Mountain Bike World Cup. Retrieved from https://www.uci.org/competition-hub/2022-mercedes-benz-uci-mountain-bike-world-cup/1XGKzkEDtWb97jeQKPLUKj

Mountain Bike: Cross-country events, § 4 (2022b).

Mountain Bike: Downhill events, § 4 (2022c).

Warden, S. J., Edwards, W. B., & Willy, R. W. (2021). Preventing bone stress injuries in runners with optimal workload. *Current Osteoporosis Reports, 19*(3), 298-307. doi:10.1007/s11914-021-00666-y

Williams, N. I., Etter, C. V., & Lieberman, J. L. (2017). The science of healthy menstruation in exercising women. *Kinesiology Review, 6*(1), 78-90.

Yang, J., Peek-Asa, C., Covassin, T., & Torner, J. C. (2015). Post-concussion symptoms of depression and anxiety in division I collegiate athletes. *Developmental Neuropsychology, 40*(1), 18-23. doi:10.1080/87565641.2014.973499

Appendices

Appendix A

Survey

Menstrual health in mountain biking - Internationally competitive

---

Start of Block: Default Question Block

Q1 The following survey aims to gain insight into the menstrual health and associated training and performance outcomes of elite female mountain bikers who are competing in the 2021 World Cups or World Championships.

Your participation in this survey is completely voluntary. You may withdraw at any point up until you submit your answers at the end of the survey. Your information relating to this study and any other information received will be kept strictly confidential. Your identity will be kept anonymous.

If you have any questions or concerns please contact the lead researcher Mary-Ann Moller, email: Mary-Ann.Moller.1@uni.massey.ac.nz

By continuing, you consent to the above. Thank you.

Q2 How old are you? (years)

____

Q3 Please indicate your main MTB discipline

◯ DH (1)

◯ XCO (2)

Display This Question:

If Please indicate your main MTB discipline = DH

Q4 During the 2021 season, which of the following will you be competing in? (please select all that apply)

☐ World Cup (1)

☐ World Championships (2)

☐ None of the above (3)

Skip To: Q7 If During the 2021 season, which of the following will you be competing in? (please select all that... = World Cup

Skip To: Q7 If During the 2021 season, which of the following will you be competing in? (please select all that... = World Championships

Skip To: Q6 If During the 2021 season, which of the following will you be competing in? (please select all that... = None of the above

---

Q5 During the 2021 season, which of the following will you be competing in? (please select all that apply)

☐ World Cup (1)

☐ World Championships (2)

☐ Tokyo Olympics (3)

☐ None of the above (4)

Skip To: Q6 If During the 2021 season, which of the following will you be competing in? (please select all that... = None of the above

---

Display This Question:

If During the 2021 season, which of the following will you be competing in? (please select all that... = None of the above

Or During the 2021 season, which of the following will you be competing in? (please select all that... = None of the above

Q6 As this survey is for women competing at the 2021 World Cups, World Championships and Tokyo Olympics, unfortunately you do not meet the required criteria. We are grateful for your interest in taking part in this research.

Skip To: End of Survey If As this survey is for women competing at the 2021 World Cups, World Championships and Tokyo Olymp... Is Displayed

---

Q7 Over the past two years, what has been your best placing in a World Cup or World Championship race?

- 1-5 (1)
- 6-10 (2)
- 11-20 (3)
- 21-30 (4)
- 31-40 (5)
- 41-50 (6)
- 51-100 (7)
- 101-150 (8)
- 150+ (9)

Q8 How long have you been competing at an international level?

- Less than 1 year (1)
- 1 to 5 years (2)
- 6 to 10 years (3)
- More than 10 years (4)

Q9 Approximately, how many hours per week do you train **out of** competition phase (no races coming up or just been)?

- <10 (1)
- 10-15 (7)
- 15-20 (8)
- 20-25 (9)
- 25-30 (10)
- >30 (11)

Q10 Approximately, how many hours per week do you train **in** competition phases (races coming up or just been)?

- <10 (1)
- 10-15 (4)
- 15-20 (5)
- 20-25 (6)
- 25-30 (7)
- >30 (8)

Q11 Have you ever been diagnosed with any of the following? (please select all that apply)

- ☐ Stress fracture(s) (1)
- ☐ Disordered eating (2)
- ☐ Asthma (3)
- ☐ Low bone density (4)
- ☐ Concussion (7)
- ☐ Depression/anxiety (8)
- ☐ Haemochromatosis (iron overload disorder) (9)
- ☐ Hypothyroidism (low thyroid activity) (5)
- ☐ Oligomenorrhea (infrequent menstrual cycle/reduced periods) (10)
- ☐ Amenorrhea (absent menstrual cycle/no periods) (11)
- ☐ None of the above (12)

Q12 Have you ever experienced undiagnosed

- ☐ Oligomenorrhea (infrequent menstrual cycle/reduced periods) (1)
- ☐ Amenorrhea (absent menstrual cycle/no periods) (2)
- ☐ None of the above (4)

Q13 Have you ever been diagnosed with iron deficiency and/or anaemia?

○ Yes (1)

○ No (2)

Q14 Have you ever used oral iron supplementation or received an iron injection or infusion?

○ Yes (1)

○ No (2)

Q15 Have you ever had surgery for gynaecological/women's health related issues?

○ Yes (1)

○ No (2)

Skip To: Q17 If Have you ever had surgery for gynaecological/women's health related issues? = No

Q16 What was the surgery for?

____

Q17 Have you ever experienced a period (menstrual bleed)?

○ Yes (1)

○ No (2)

Skip To: Q21 If Have you ever experienced a period (menstrual bleed)? = No

Q18 How old were you when you had your first period?

____

Q19 Did your first period occur naturally (i.e. without medical intervention)?

- ◯ Yes (1)
- ◯ No (3)

Skip To: Q21 If Did your first period occur naturally (i.e. without medical intervention)? = Yes

Q20 What kind of treatment was used to start your menstrual cycle? (select all that apply)

- ▢ Hormonal treatment (1)
- ▢ Weight gain (2)
- ▢ Reduced amount of exercise (3)
- ▢ Increased nutritional intake (4)
- ▢ Other (please specify) (5) ____

Q21 Has a doctor ever told you that you might have any of the following conditions? (select all that apply)

- ▢ Polycystic ovary syndrome (1)
- ▢ Endometriosis (2)
- ▢ Premature ovarian failure (early menopause) (3)
- ▢ Excess of hormone prolactin (4)
- ▢ Female athlete triad or relative energy deficiency in sport (RED-S) (5)
- ▢ Any other gynaecological diagnosis (please specify) (6) ____
- ▢ None of the above (7)

Q22 Have you ever used hormonal contraception (for any reason)?

- ○ Yes, and currently using hormonal contraception (1)
- ○ Yes, but no longer using hormonal contraception (2)
- ○ No, I have never used hormonal contraception (4)

Skip To: Q27 If Have you ever used hormonal contraception (for any reason)? = No, I have never used hormonal contraception

---

Q23 Which hormonal contraception are you currently using, or have you most recently used?

- ☐ Combined oral contraceptive pill (examples include: Ava, Loette, Levlen, Microgynon, Microlut, Norimin, Yasmin or Yaz, Ginet or Estelle, Monofemme, Mercilon) (1)
- ☐ Progesterone only pill/"mini pill" (examples include: Cerazette, Noriday) (2)
- ☐ Hormonal intrauterine contraceptive device (examples include: Mirena IUD, Jaydess IUD) (3)
- ☐ Depot injection (4)
- ☐ Jadelle implant (5)

Q24 Why did/do you use this? (select all that apply)

- ☐ To make my periods regular (1)
- ☐ To reduce period pain (2)
- ☐ To try to skip period (3)
- ☐ To reduce acne (4)
- ☐ Contraception (5)
- ☐ To prevent injury (6)
- ☐ Unsure; I was prescribed it by my doctor (7)
- ☐ Other (please specify) (8) ____

Q25 How long did/have you used this form of hormonal contraceptive for?

- ○ Less than 3 months (1)
- ○ 3-6 months (4)
- ○ 7-12 months (5)
- ○ More than 1 year (6)

Q26 Have you experienced any of the following side effects from this hormonal contraceptive? (select all that apply)

- ☐ Weight gain (1)
- ☐ Weight loss (2)
- ☐ Heavy periods (3)
- ☐ Light or no period (4)
- ☐ Migraines (5)
- ☐ Performance deficit (6)
- ☐ Performance enhancement (7)
- ☐ Mood disturbance (8)
- ☐ Breast tenderness (9)
- ☐ Acne (10)
- ☐ No side effects (11)
- ☐ Other (please specify) (12) ____

Q27 How many periods have you had in the last 12 months?

- ○ Less than 3 (1)
- ○ 3 to 8 (4)
- ○ 9 to 12 (5)
- ○ 13 to 15 (6)
- ○ More than 15 (7)

Q28 Do you track your menstrual cycle?

- ○ Yes (1)
- ○ No (2)

Skip To: Q30 If Do you track your menstrual cycle? = No

Q29 How do you track your menstrual cycle? (select all that apply)

- ▢ Training software (1)
- ▢ Smart phone App (2)
- ▢ Paper or electronic diary (3)
- ▢ Other (please specify) (4) ____

Q30 When you don't use hormonal contraception are your periods regular? (21-35 days)

○ Yes (1)

○ No (2)

○ Don't know (3)

○ I have never used a form of hormonal contraception (4)

Q31 Relating to your menstrual cycle do you experience any of the following symptoms? (please select all that apply)

- ☐ Pelvic pain (pain in the lower part of your belly) (1)
- ☐ Pain when opening your bowels (2)
- ☐ Bleeding when opening your bowels (3)
- ☐ Pain on passing urine (4)
- ☐ Blood in your urine (5)
- ☐ Low back pain (6)
- ☐ Deep pelvic pain during sex (7)
- ☐ Pain in upper legs or thighs (8)
- ☐ Nausea or vomiting (9)
- ☐ Increased fatigue (10)
- ☐ Disrupted sleep (11)
- ☐ Headaches (12)
- ☐ Other (please specify) (13) ____
- ☐ None of these (14)

Q32 Do you take pain relief during your period?

- ○ Yes (1)
- ○ No (2)

Q33 Do you consider your periods to be heavy?

- ○ Yes (1)
- ○ No (2)

Q34 During your period do you regularly (select all that apply)

- ▢ Pass large clots of blood (1)
- ▢ Flood through your protection to clothes or bedding (2)
- ▢ Need to very frequently change sanitary pads or tampons (3)
- ▢ Need to wear double sanitary protection (4)
- ▢ Struggle to complete training without changing protection (5)
- ▢ None of these (6)

Q35 When your training volume, intensity or duration changes do you experience changes in your menstrual cycle?

- ○ Yes (1)
- ○ No (2)
- ○ Don't know (3)

Skip To: Q37 If When your training volume, intensity or duration changes do you experience changes in your menstr... = No

Skip To: Q37 If When your training volume, intensity or duration changes do you experience changes in your menstr... = Don't know

Q36 What specific changes in your menstrual cycle do you notice when you reduce training volume, intensity, or duration?

☐ I bleed less (1)

☐ I bleed more (2)

☐ I bleed fewer days (3)

☐ I bleed more days (4)

☐ My monthly bleeding stops (5)

☐ My monthly cycle is more regular (6)

☐ My monthly cycle is less regular (7)

☐ Other (please specify) (8) ____

Q37 In the last six months have you missed or modified any training due to menstrual cycle related symptoms?

○ Yes (1)

○ No (2)

Skip To: Q40 If In the last six months have you missed or modified any training due to menstrual cycle related sy... = No

---

Q38 How many times in the last six months have you had to miss or modify a training session due to menstrual cycle related symptoms?

○ 1 to 5 times (4)

○ 6 to 10 times (5)

○ More than 10 times (6)

Q39 Relating to your menstrual cycle what symptoms have caused you to miss or modify training? (please select all that apply)

- ▢ Heavy bleeding (1)
- ▢ Severe pain or cramps (2)
- ▢ Fatigue (3)
- ▢ Nausea or vomiting (4)
- ▢ Diarrhoea or constipation (5)
- ▢ Body aches (6)
- ▢ Low mood (7)
- ▢ Lack of motivation (8)
- ▢ Headache (9)
- ▢ Other (please specify) (10) ____

Q40 In the last four years (Olympic cycle) have you missed a race due to menstrual cycle related symptoms?

- ○ Yes (1)
- ○ No (2)

Skip To: Q42 If In the last four years (Olympic cycle) have you missed a race due to menstrual cycle related symp... = No

Q41 What menstrual cycle related symptoms have prevented you from racing? (please select all that apply)

- ▢ Heavy bleeding (1)
- ▢ Severe pain or cramps (2)
- ▢ Fatigue (3)
- ▢ Nausea or vomiting (4)
- ▢ Diarrhoea or constipation (5)
- ▢ Body aches (6)
- ▢ Low mood (7)
- ▢ Lack of motivation (8)
- ▢ Headache (9)
- ▢ Other (please specify) (10) ____

Q42 In the last four years do you believe menstrual cycle related symptoms have impacted your performance? (select all that apply)

- ☐ Yes, I go better when I have my period (1)
- ☐ Yes, I go worse when I have my period (2)
- ☐ Yes, I go better when I am ovulating (3)
- ☐ Yes, I go worse when I am ovulating (4)
- ☐ No, it doesn't seem to affect my performance (5)
- ☐ I am not sure (6)

Q43 Do you or have you used medication to prevent menstruation during a race?

- ○ Yes (1)
- ○ No (2)

Skip To: Q45 If Do you or have you used medication to prevent menstruation during a race? = No

---

Q44 What medication have you used?

____

Q45 Have you used any of the following to try to obtain the "ideal" body for performance or appearance reasons? (please select all that apply)

- ☐ Dieting or very restrictive nutrition practices (1)
- ☐ Training on rest days (2)
- ☐ Use of laxatives (3)
- ☐ Vomiting or purging (4)
- ☐ Use of medication or supplements (5)
- ☐ Other (please specify) (6) ____
- ☐ No, this doesn't apply to me (7)

Q46 Do you discuss menstrual cycle related issues with your coach?

- ○ Yes (1)
- ○ No (2)

Q47 Do you experience any barriers communicating menstrual-related issues with support staff?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Do you experience any barriers communicating menstrual-related issues with support staff? = No

---

Q48 Specifically do you experience any barriers with (select all that apply)

- ▢ Female coach (1)
- ▢ Male coach (2)
- ▢ Female sports scientist (3)
- ▢ Male sports scientist (4)
- ▢ Female nutritionist (5)
- ▢ Male nutritionist (6)
- ▢ Female doctor (7)
- ▢ Male doctor (8)
- ▢ Female strength and conditioner (9)
- ▢ Male strength and conditioner (10)
- ▢ Female physiotherapist (11)
- ▢ Male physiotherapist (12)

Q49 What do you perceive are the barriers?

- ▢ Gender of staff (1)
- ▢ Lack of staff knowledge of these issues (2)
- ▢ Stigma of this topic (3)
- ▢ Concerns about the nature of the conversation impacting your position in sport/team (eg. deselection from competition) (4)
- ▢ Cultural differences between yourself and staff (5)
- ▢ Other (please specify) (6) ____

End of Block: Default Question Block

Appendix B

Supplementary table 1

Table A1. *Statistical tests and results.*

Variable 1	Variable 2	Results of interest	Test used	Test statistic	P value
Training volume – IN competition	Training volume – OUT of competition	Higher out of competition than in competition	Wilcoxon signed rank test	*V* = 1524	<.001
MD	Age	No differences	Welch Two Sample *t*-test	*t* = -.88 *df* = 73.6	.38
	Discipline	No differences	Pearson's Chi-squared test	χ^2 <.001 *df* = 1	1.0
	Training volume – IN competition	No differences	Mann Whitney *U* test	*W* = 778	.38
	Training volume – OUT of competition	No differences	Mann Whitney *U* test	*W* = 692	.89
Diagnosed amenorrhea	RED-S/female athlete triad	Amenorrhea higher in those with RED-S	Fisher's exact test	Fisher's *P*	.01
Undiagnosed amenorrhea	Disordered eating practices (count)	Undiagnosed amenorrhea higher in those who engaged in greater number of DE practices	Welch Two Sample *t*-test	*t* = -2.72 *df* = 74	.008
Discipline	Concussion	Concussions higher in DH than XCO	Pearson's Chi-squared test	χ^2 = 4.93 *df* = 1	.026
Injuries (count)	Depression/ anxiety	Higher proportion of depression in those who had injuries	Pearson's Chi-squared test	χ^2 = 6.30 *df* = 1	.012
Disordered eating	Low bone density	LBD higher in those with DE	Fisher's exact test	Fisher's *P*	.02
	RED-S/female athlete triad	RED-S higher in those with DE	Fisher's exact test	Fisher's *P*	.007
Disordered eating practices (count)	Training volume – IN competition	Non-significant trend with higher training volume and more DE practices	One-way ANOVA	*F* = 2.25	.073

Variable 1	Variable 2	Results of interest	Test used	Test statistic	*p* value
RED-S/female athlete triad	Disordered eating practices (count)	Higher proportion of RED-S with greater number of DE practices	Welch Two Sample *t*-test	*t* = -2.56 *df* = 7.09	.037
	Training volume – IN competition	Higher proportion of RED-S with higher training volume	Mann-Whitney *U* test	*W* = 80.5	.001
	Training volume – OUT of competition	Higher proportion of RED-S with higher training volume	Mann-Whitney *U* test	*W* = 84	.001
	Low bone density	Those that had LBD also had RED-S	Fisher's exact test	Fisher's *P*	.007
	Hypothyroid-ism	Higher proportion of RED-S with hypothyroidism	Fisher's exact test	Fisher's *P*	.040
	Competition age	Higher proportion of RED-S with increased competition age	Mann-Whitney *U* Test	*W* = 125	.014
Hormonal contraceptive use	Age	No age related differences	Welch Two Sample *t*-test	*t* = .987 *df* = 52.6	.34
	Discipline	No differences	Fisher's exact test	Fisher's *P*	1.00
	Training volume – IN competition	No differences	Mann-Whitney *U* test	*W* = 565	.75
	Training volume – OUT of competition	No differences	Mann-Whitney *U* test	*W* = 563	.78
Menstrual cycle symptoms (count)	Age	No age related differences	One-way ANOVA	*F* = .726	.67
	Discipline	No differences	Welch two-sample *t*-test	*t* = 1.34 *df* = 17.3	.20
	Training volume – IN competition	No differences	One-way ANOVA	*F* = .486	.75
	Training volume – OUT of competition	No differences	One-way ANOVA	*F* = .022	.88

Subset; World Class XCO and World Class DH data only					
Variable 1	**Variable 2**	**Results of interest**	**Test used**	**Test statistic**	***p* value**
Discipline	Age	Non-significant trend in older riders in World Class DH than World Class XCO	Welch two-sample *t*-test	$t = 1.88$ $df = 8.60$	.094
	Training volume – IN competition	Not significant	Mann-Whitney *U* test	$W = 55$	.84
	Training volume – OUT of competition	Not significant	Mann-Whitney *U* test	$W = 34.5$	.16
	Total amenorrhea	Not significant	Fisher's exact test	Fisher's *P*	1.00
	Total oligomeno-rrhea	Not significant	Fisher's exact test	Fisher's *P*	1.00
	MD	Not significant	Fisher's exact test	Fisher's *P*	1.00
	Iron deficiency/ anaemia	Not significant	Fisher's exact test	Fisher's *P*	1.00
	Depression/ anxiety	Not significant	Fisher's exact test	Fisher's *P*	.56
	Concussion	Non-significant trend towards more concussions in DH	Fisher's exact test	Fisher's *P*	.054
	Negative HC symptoms	Not significant	Welch two sample *t*-test	$t = -1.38$ $df = 14$	.19
	Heavy menstrual bleeding	Non-significant trend towards higher HMB in DH	Fisher's exact test	Fisher's *P*	.054
	MC symptoms (count)	Non-significant trend towards more MC symptoms in DH	Welch two sample *t*-test	$t = 1.95$ $df = 10.34$	.078
	Disruption to training	Non-significant trend towards greater disruption in DH	Fisher's exact test	Fisher's *P*	.074