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To cite this article: Emma O'Loughlin, Duncan Reid & Stacy Sims (10 Oct 2023): The role of menstrual cycle phase-based resistance training for women post anterior cruciate ligament reconstruction: a scoping review, Physical Therapy Reviews, DOI: [10.1080/10833196.2023.2266320](https://doi.org/10.1080/10833196.2023.2266320)

To link to this article: <https://doi.org/10.1080/10833196.2023.2266320>



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Published online: 10 Oct 2023.



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The role of menstrual cycle phase-based resistance training for women post anterior cruciate ligament reconstruction: a scoping review

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ABSTRACT

Background: Strength deficits are common following anterior cruciate ligament reconstruction (ACLR). Best practice guidelines recommend resistance training post-ACLR to target these strength deficits. Research has supported menstrual cycle (MC) phase-based resistance training for eumenorrheic women, however its applicability for women post-ACLR was unknown.

Objectives: This study aimed to establish whether there was a role for MC phase-based resistance training for women post-ACLR.

Methods: Authors searched seven databases (MEDLINE, Scopus, CINAHL, SportDiscus, Web of Science, Cochrane Library, and Google Scholar) between 6/12/21 – 22/12/22. Primary studies or reviews describing MC phase-based resistance training at least one MC duration, published in academic journals, and written in English were included. Studies which investigated the effect of the oral contraceptive pill on training responses were excluded.

Results: The search yielded 1942 titles and abstracts, with 14 studies included in the final analysis (eight primary studies). No studies were found that investigated MC phase-based resistance training in women post anterior ligament reconstruction. Studies were limited by methodological issues. Six primary studies supported follicular phase-based training to enhance responses, including superior strength, power, lean mass gain, and reduced dysmenorrhea symptoms. One study reported no difference in strength gain between follicular and luteal phase-based resistance training, and another study reported that underweight participants obtained superior strength gain following luteal phase-based resistance training.

Conclusions: The results suggest that MC phase-based training may influence responses pertinent to women post-ACLR. There is scope for future research to investigate follicular phase-based resistance training in women following ACLR.

ARTICLE HISTORY

Received 8 March 2022

Accepted 12 September 2023

KEYWORDS



Physical therapy modalities; sports medicine; resistance training; knee; muscle strength


Introduction

The participation of women involved in sports has increased more than tenfold in the last four decades [1]. In line with this increased participation in sports, there has also been an increase in anterior cruciate ligament (ACL) injuries in women [2]. After an ACL injury, most athletes undergo ACL reconstruction (ACLR) surgery [2]. There has been a noted increase in women undergoing ACLR in New Zealand [2]. This increase in women undergoing ACLR is not unique to New Zealand but is an international phenomenon [3].

Best practice guidelines recommend that resistance training (RT) programmes commence six weeks post-ACLR to target strength deficits [4]. After surgery, athletes attend rehabilitation with physiotherapists to

target these postoperative strength deficits, prepare to return to sport, and prevent reinjury. Strength deficits in the quadriceps and hamstring muscle groups are common following ACLR [5]. Women have reduced quadriceps and hamstring strength recovery of their injured leg post-ACLR compared to men, despite similar timeframes post-surgery, pre-injury activity levels, and graft source [5]. In particular, inferior quadriceps recovery is of concern as persistent impairments in quadriceps strength are associated with reduced patient outcomes, including reduced function, inferior activity levels and increased reinjury rates [5–7]. In line with this inferior quadriceps strength recovery, women display significantly inferior knee function, report reduced activity levels, and are less likely to return to sports following ACLR

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 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/10833196.2023.2266320>.

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than men [8]. Subsequently, restoring lower limb strength, particularly quadriceps strength, is a leading rehabilitation priority for women post-ACLR [6].

These postoperative RT programmes provide a stimulus for muscular adaptation. Many factors mediate muscular adaptations, including the physical stress placed on the body (training volume, loading and frequency), recovery, diet, sleep, and hormonal responses to RT [9–11]. In eumenorrheic women, following puberty and prior to menopause, despite intra- and inter-individual variation, the steroid hormones oestrogen & progesterone fluctuate in a predictable rhythm throughout the menstrual cycle (MC). Oestrogen is known to have an anabolic effect on skeletal muscle [12]. This anabolic effect is partly due to antioxidant, membrane stabilizing and neuro-excitatory effects, including satellite cell activation and proliferation [13,14]. In contrast, progesterone has anti-oestrogenic effects and is considered catabolic [15]. Furthermore, hormonal variations in oestrogen can influence motivation and mood, affecting training motivation [16].

Previous research has investigated hormonal fluctuations' chronic effects on RT adaptations [17,18], specifically MC phase-based RT, where women periodize RT around their MC phases. In follicular phase (FP)-based RT, resistance exercise is performed in the FP when oestrogen and progesterone concentrations are low, and oestrogen slowly rises to a pre-ovulatory surge [17]. Research has compared FP-based training with linear/unilateral training, where RT is not periodized specific to the MC, and luteal phase (LP)-based RT, where high volume and intensity RT is specific to the LP. Throughout phase-based RT, women track their MCs using various methods, including calendar tracking, basal body temperature testing, urinary ovulation kits, and serum blood analysis. A recent systematic review supported specific FP-based RT for enhanced RT strength outcomes in eumenorrheic women [19]. It suggested that athletes with an ovulatory MC concentrate on RT during the FP of their MC [19].

However, this systematic review did not include or discuss recommendations or applications for women completing RT as part of rehabilitation. It is expected that a woman post-ACLR would respond similarly to a non-injured woman engaging with MC phase-based RT. Nevertheless, it is still being determined whether the protocols and results of previous MC phase-based RT research with non-injured women are relevant or applicable to women post-ACLR. Given the implications of maximal quadriceps strength recovery post-ACLR and women's specific need for this increased strength recovery, it is pertinent to investigate the efficacy of MC phase-based RT in this population.

For these reasons, this scoping review was conducted to establish current literature in this area, identify gaps in knowledge, and propose future research directions. A scoping review was considered most suitable, as scoping reviews are exploratory and aim to map critical concepts underpinning a complex research area [20]. The overarching research question is: Is there a role for MC phase-based RT for women post-ACLR? The review will address the following questions: (1) Have MC phase-based RT programmes been investigated in women post-ACLR? (2) What is known about the methodologies of MC phase-based RT programmes? (3) What is known about the effects of MC phase-based RT? and (4), Do these findings provide a gap for future experimental studies in an ACLR rehabilitation context?

Materials and methods

This scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for scoping reviews [21] and the Joanna Briggs Institution review manual [22] based on the original five stages scoping review methodology [23]. An a priori scoping review protocol was developed and is registered on the Open Science Framework (<https://doi.org/10.17605/OSF.IO/9FNJP>) and has been previously published [24]. The scoping review has one variation from the protocol. The authors broadened the scope of the third review question from 'what is known about menstrual cycle phased RT effects on strength outcomes and motivation for training?' to 'what is known about the effects of MC phase-based RT?' The authors broadened the question as more results from included studies were considered relevant for women post-ACLR (pain symptoms, fat-free mass, adherence to exercise, participant preference).

Eligibility criteria

The review included any primary research study which reported outcomes following MC phase-based RT of at least one MC duration. Initial searching did not find any studies investigating MC phase-based RT in injured women; therefore, the final search strategy included naturally cycling women regardless of injury status. Similarly, the review included studies which investigated both MC phase-based RT and oral contraceptive pill (OCP) phase-based RT (i.e. exercises periodized to the sugar pill week versus the rest of the month). These studies were included as they provide information regarding MC phase-based training [25]. In addition, the review included narrative, systematic and scoping

reviews and if they discussed methodologies or effects of MC phase-based RT. Reviews were included as they provided a wide historical overview of the research area and the comparison of the review findings with the current body of knowledge offered valuable insights into the current research area. Studies must have been published in English to be reviewed by the research team (EOL, DR, SS) and assessed for suitability. The review did not use date restrictions, but studies must have been published in peer-reviewed academic journals to ensure a minimum quality standard. The review excluded studies that specifically investigated the effect of the OCP on RT responses, as women taking the OCP have different hormonal profiles from those with a natural MC. This review aimed to investigate the effect of the endogenous MC only.

Search strategy

In March 2020 and October 2021, the primary author (EOL) and an experienced librarian performed pilot tests of study selection procedures (Supplementary Material 2). These searches tested the literature search strategy and proposed study selection criteria. The results, keywords, and index terms were reviewed by the primary author (EOL) and the librarian (MF). No studies were found that investigated MC phase-based RT for women following an ACL injury. Zero studies met the criteria after abstract review. This pilot exercise informed the development of the complete search strategy by the librarian (MF) and the primary author (EOL) to include broader search terms. These broader terms aimed to find studies examining MC phase-based training in women regardless of injury status (Supplementary File 2). Searching was then undertaken in the following databases: CINAHL, Medline, SportsDiscus, Web of Science, Scopus, the Cochrane Central Library, and Google Scholar (Supplementary File 2). Following the search, all identified citations were collated and uploaded into EndNote V17 (Clarivate Analytics, PA, USA), and duplicates were removed.

Study/source of evidence selection

Relevant titles and abstracts were independently evaluated against the eligibility criteria by two authors (EOL, DR). If there were no consensus regarding inclusion or exclusion decisions, the study proceeded to a full-text review. Potentially relevant sources were retrieved in full. The full text of selected citations was assessed in detail against the inclusion criteria by two authors (EOL, DR). The primary author sent each screening step's Endnote

Library (Clarivate Analytics, PA, USA) to the other authors (SS), who agreed with all included studies. Subsequently, reference list and citation searching were carried out on Ovid. All potentially relevant citations were collated and uploaded into EndNote V17 (Clarivate Analytics, PA, USA). Relevant titles and abstracts were evaluated against the eligibility criteria by two authors (EOL, DR), and two authors (EOL, DR) assessed relevant full texts. Initial searching took place between 6/12/21 – 14/12/21, and the search was updated during the manuscript peer review on 22/12/22.

Data extraction

The authors adapted the data charting form used in this review from the Joanna Briggs Manual template (Supplementary File 3) [22]. The primary and secondary authors (EOL, DR) independently extracted the data from all studies. In line with guidelines for scoping review methodology, the review did not conduct a methodological quality appraisal of the included studies [21].

Results

A review flow diagram summarises the results from the search process (Figure 1). The initial database search results yielded 1,250 records after duplicates were removed. After the exclusion of 1,196 records during the title/abstract screening, a total of 54 studies were retained for full-text screening. A further 41 reports were excluded at full-text screening. The excluded studies' names and reasons for exclusion are reported in Supplementary File 4. With the addition of one extra study identified from reference list screening & citation searching, the final number of included studies was 14 (see Figure 1 and Supplementary File 4). These 14 studies included eight primary research studies and six review articles. All eight primary studies compared FP-based RT to LP-based RT or regular RT. In addition, the study also included one systematic review and five narrative reviews. Results are summarized as to the research questions and in Table 1.

Participants

No women with ACL injuries were included as participants in any of the included studies. All studies included non-injured participants. However, Zainab et al. [29] included 150 university students with moderate to severe primary dysmenorrhea. Many primary studies had low participant numbers (median $n = 20$, minimum $n = 7$, maximum $n = 150$). Among the six original research studies,

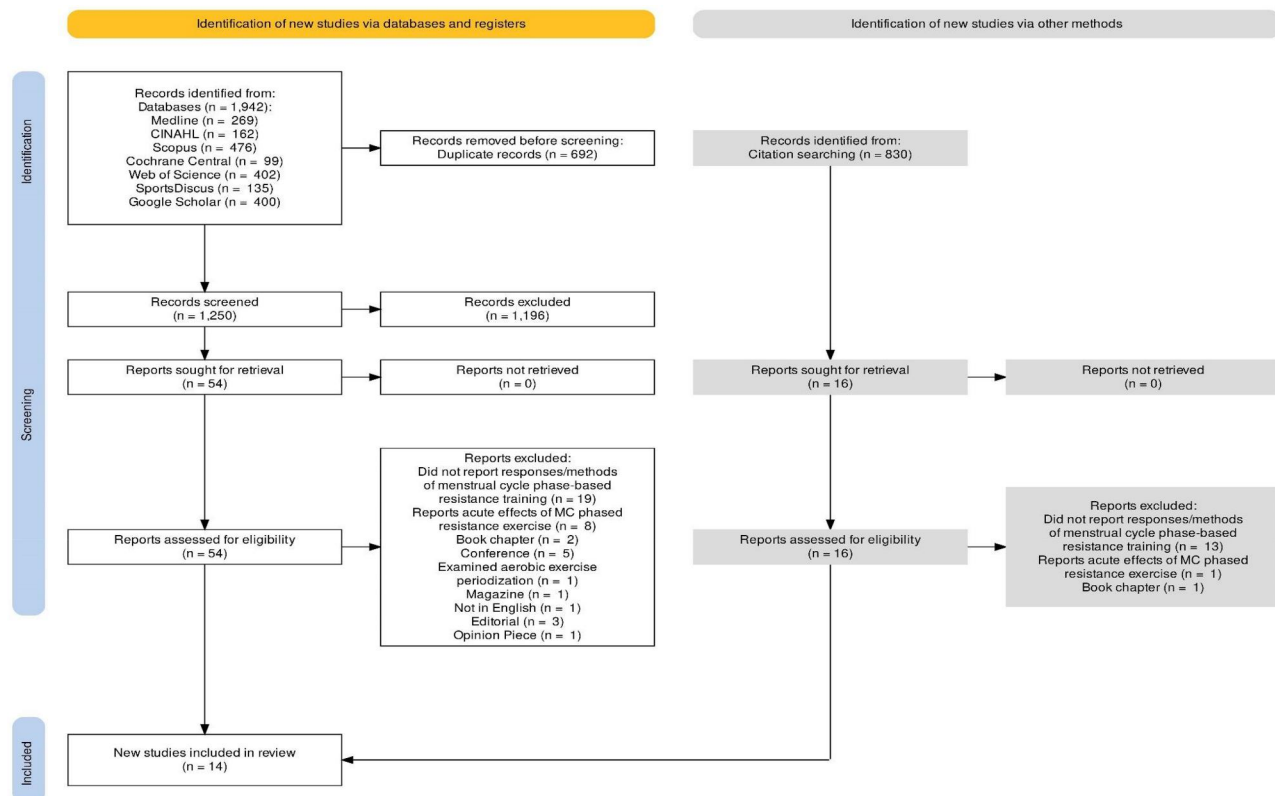


Figure 1. PRISMA flow diagram.

three included participants who were not resistance-trained [17,27,28]. Additionally, two studies did not provide information on the training status of the participants [18,29]. In addition, Sung and Kim [28] did not report the number of participants in each training group or how they distributed subgroups of participants with different BMI levels between phase-based training groups.

The two studies by Wikström-Frisén et al. [25,26] included 59 participants who had previous experience with RT for leg press & leg curl for a minimum of two months, three times per week before the start of the study. In these studies, MC-phase and OCP-based training were combined, with OCP users ($n = 32$) and non-OCP users ($n = 27$) distributed evenly throughout the three groups. Vargas-Molina et al. [30] included women with two months of three times weekly RT experience for two months or more. Participants who served as their own control were included in four studies [25,26,28,29], whereas the remaining four studies utilized a control group [25,26,28–30].

The systematic review by Thompson et al. [19] included 418 women aged 18–38 years to identify the effect of the MC on acute and chronic responses to RT, and the effect of the OCP on responses to RT. All other reviews were narrative reviews, which did not have defined participant inclusion criteria.

RT programme design

In four studies, resistance training (RT) programs with a duration of twelve weeks were included [17,27–29]. Two studies reported eight-week RT programs [18,30], and the studies by Wikström-Frisén et al. [25,26] described a sixteen-week RT program. Lower limb RT exercises, including knee extension exercises [18,28], leg press [17,25,26], and leg curls [25,26], were included in four studies. The study by Sakamaki-Sunanga et al. [27] included arm curls, the study by Vargas-Molina et al. [30] included a mix of upper and lower limb exercises, including bench press and squat training, whilst a study by Zainab et al. [29] included core RT, including crunches, pelvic bridges, superman exercise, and bilateral single-leg raises, forearm planks, side planks, and cat and camel exercises.

Most studies provided guidance on RT parameters, including exercise session frequency and progression protocols. In terms of recommended sets and repetitions, six studies recommended either 2–3 sets of 8–15 repetitions at 80% of the repetition maximum [17,18,28], or 8–12 repetitions maximum [25–27]. Zainab et al. [29] recommended ten reps of each exercise prescribed per day. Interestingly, only Vargas-Molina et al. [30] prescribed the same number of sessions per week but varied the RT session

Table 1. Study characteristics of primary studies and reviews that met inclusion criteria.

Author, Year, Location	Study Design & Duration	Population	Study Design/Review Aim	Comparison	MC Verification	Results	Conclusions
Reis et al. 1995 [18] Germany	Non-randomized controlled trial. 8 weeks	N = 7 students. Training status not noted. Non-injured. Age: 24 ± 3.5 years	Lower limb unilateral knee extension RT every second day in the FP. Rest or x1/week in LP.	Opposite leg carried out lower limb unilateral knee extension RT every third day throughout the MC (regular training).	BBT, ovulation kits, & blood serum analysis. N = 1 excluded by blood analysis.	20% increase maximum knee extension strength difference in FP-based RT group.	FP based RT is superior for strength development.
Sung et al. 2014 [17] Germany	Randomised controlled trial. 12 weeks	N = 20 untrained students. Non-injured. Age: 25.9 ± 4.5 years	8 lower limb unilateral leg press RT sessions in FP & 2 in LP per MC.	Opposite lower limb completed 8 lower limb unilateral leg press RT sessions in LP & 2 in FP per cycle.	Calendar tracking, BBT, & blood serum analysis N = 4 excluded by BBT analysis	29% increased maximum knee extension strength in FP-based RT group. FP-based RT group also showed a higher increase in muscle CSA than LT. Increase in fibre diameter of type II fibres and in cell nuclei-to-fibre ratio only after FP-based RT.	FP based RT is superior for strength development & muscle CSA.
Wikström-Frisén et al. 2017 [25] Sweden	Randomised Controlled trial 16 weeks	N = 59 N = 32 using OCP, N = 27 no OCP. x3/week > 2 months RT experience. Non-injured. Age: 25 ± 4 years	Group 1: Leg press and leg curl RT x5/week in FP. Group 2: Leg press and leg curl RT 5 days/week in LP. x1/week in FP.	Control group: Leg press and leg curl RT 3 days/week during MC.	Calendar tracking Exclusion if cycle >35 days. n = 2 excluded.	Increased squat jump and muscle strength for FP based RT compared to LP. Control group greater strength compared to LP based RT. Increased LBM in FP group only.	High volume FP based RT is superior to optimize results compared to LP based RT. FP based RT also resulted in larger LBM compared to regular training.
Wikström-Frisén et al. 2016 [26] Sweden	Randomised Controlled trial 16 weeks	N = 59 N = 32 using OCP N = 27 no OCP x3/week > 2 months RT experience. Non-injured. Age: 25 ± 4 years N = 14 Untrained, uninjured. Age: 21 ± 2 years	Group 1: Leg press and leg curl RT x5/week in FP. Group 2: Leg press and leg curl RT 5 days/week in LP. x1/week in FP. Upper limb unilateral dumbbell curls RT 3 days/week in FP, and 1 day/week in LP.	Control group: Leg press and leg curl RT 3 days/week during MC.	Calendar tracking. Exclusion if cycle >35 days. n = 2 excluded.	No negative impact on sex and growth hormones, body fat, bone mineral density in either group. Participants preferred FP based RT.	FP based RT was not associated with negative hormonal consequences & is well accepted by participants.
Sakamaki-Sunaga et al. 2016 [27] Japan	Non-randomized controlled trial 12 weeks	N = 36 sedentary or recreationally active. Non-injured. Age: 25 ± 7 years	Intervention group: Leg extension RT x8 times in FP and x2 times in LP.	Opposite arm unilateral dumbbell curls RT 3 days/week in LP and 1 day/week in FP. Control group: Leg extension RT x8 times in LP and x2 times in FP.	BBT. No exclusion criteria.	No difference in maximum voluntary contraction or muscle CSA.	No difference between FP and LP based RT adaptations.
Sung and Kim. 2019 [28] Korea	Non-randomized controlled Trial 12 weeks	N = 150 students with primary dysmenorrhea. Training status not noted. Age = 18–22 years N = 14. 2 years of RT experience. Non	Group A: N = 75. Performed RT (10 core exercises) daily in FP Group 1: N = 7 Strength training during the FP, hypertrophy training	Group B: N = 75 Performed RT (10 core exercises) daily in LP	No MC verification. No exclusion criteria.	Group A had decreased WALIDD score, & increased QoL more than Group B	Completing core RT during the FP is more effective as compared to LP based RT.
Zainab et al. 2021 [29] India	Randomised controlled trial 12 weeks	N = 14. 2 years of RT experience. Non	Group 1: N = 7 Strength training during the FP, hypertrophy training	Group 2: N = 7 Undulating training divided into 4	Urinary ovulation testing	Strength increases were observed for both groups, with bench press favouring Group 1. Only	The MC tailored program benefited bench press and CMJ performance.

(continued)

Table 1. Continued.

Author, Year, Location	Study Design & Duration	Population	Study Design/Review Aim	Comparison	MC Verification	Results	Conclusions
Knowles et al. 2019 [31]	Narrative Review	injured. Age: 26.6 ± 3.0 years	during ovulation, muscular endurance during LP, and recovery during the premenstrual phase.	phases per month: strength, hypertrophy, muscular endurance, and recovery.	N/A	Group 1 showed differences in CMJ. A significant increase in LBM was observed for Group 2, however absolute changes favoured Group 1.	Limited by small sample. Future studies should seek to investigate the topic employing a larger sample. Current evidence suggests possible RT practices that could optimize performance outcomes in women, although further research is warranted.
Thompson et al. 2020 [19]	Systematic Review	No inclusion criteria	Overview the current research regarding RT performance and muscle adaptation in women, focused on hormonal variables that may influence RT outcomes.	N/A	N/A	Muscle adaptation may be optimized by emphasizing FP based RT, or with combined strength/power training through the MC.	Results appear to suggest that female hormones may affect RT responses.
Randell et al. 2021 [32]	Narrative Review	N = 17 included studies (n = 418 women) Age: 18–38 years.	Identify and critically appraise current studies on the effect of the MC and OCP on responses to RT.	N/A	N/A	Conflicting findings, small participant numbers & methodological issues.	
	Narrative Review	No inclusion criteria	Discuss research addressing other major topics relating to women soccer players.	N/A	N/A	Greater responses to training have been observed in studies when higher frequency RT was performed in the FP compared to the LP or compared to regular training	Phase-based RT is a promising area to maximize responses. Further research is required before implementation, noting the logistical challenges of personalizing loads in squads.
Hansen et al. 2018 [33]	Narrative Review	No inclusion criteria	Aim: Review the literature regarding the effect of female hormones on muscle and tendon collagen protein turnover and mass.	N/A	N/A	Future trials are needed to clarify the effects of the oestrogens on muscle biology under different conditions, e.g. phase of MC.	The number of studies within the area is still limited.
Gharahdaghi et al. 2020 [34]	Narrative Review	No inclusion criteria	Aim: Provide an update on advances in RT induced hormonal responses and their impact on muscle adaptation.	N/A	N/A	RT in late FP appears to result in increased fibre type II CSA, nuclei to fibre ratio and muscle mass, compared to RT during LP. This has not been confirmed.	Future trials are needed to clarify the effects of the oestrogens on muscle biology under different conditions, e.g. phase of MC.
Oosthuysen et al. 2023 [35]	Invited Review	No inclusion criteria	Aim: Outline recent advances in ovarian hormone molecular signaling that elucidates the mechanisms for menstrual phase variability in exercise metabolism.	N/A	N/A	Progesterone increases protein catabolism during the LP by indeterminate mechanisms. Satellite cell function supported by estrogen-targeted gene expression is countered by progesterone, which explains greater muscle strengthening from FP-based RT.	Causative effects are provided by the review. The review also highlights research opportunities and evidence-based relevance for women athletes, including FP-based RT.

MC: Menstrual Cycle. OCP: Oral Contraceptive Pill. LP: Luteal Phase. FP: Follicular Phase RT: Resistance training BB7: Basal Body Temperature. LH: Luteinising Hormone. N/A: Not Applicable. N=: Number of Participants TRM: 1 Repetition Maximum Test. LBM: Lean body mass. CMJ: Counter Movement Jump. WALIDD: Working ability, Location, Intensity, Days of Pain, Dysmenorrhea score. QoL: Quality of Life.

to participants' MC phase. Vargas-Molina prescribed strength training during the FP (3–5 repetition maximum load until one or two reps before failure, then a three-minute break between sets), hypertrophy training during the ovulatory phase (eight to ten repetition maximum load until failure, then a 90-second break between sets), muscular endurance during LP (20–25 repetition maximum load until failure, then a 45-second break), and recovery (12–15 repetition load), during the premenstrual phase.

Studies provided different participation adherence rates; Sung et al. [17] reported 92% adherence, Sakamaki-Sunaga et al. [27] reported 100% adherence, and Vargas-Molina et al. [30] excluded two participants due to non-adherence to training. Wikström-Frisén et al. [25] reported that participants in both groups had equal adherence as per participant training logs.

MC verification methods

All primary studies used different methods to track and verify participants' MC phase and status. Reis et al. [18] used basal body temperature testing, ovulation prediction kits and blood serum analysis to confirm participants' MC phase. Similarly, Sung et al. used [17] calendar tracking, basal body temperature and serum blood analysis to verify participants' MC phase. In contrast, Sakamaki-Sunaga et al. [27] and Sung and Kim [28] used basal body temperature only to verify the MC phase, whilst Wikström-Frisén et al. [25,26] used calendar tracking only, and Vargas-Molina et al. [30] utilized ovulation testing only. Zainab et al. [29] did not report any MC verification method. Three studies excluded participants who did not meet stipulated MC criteria [17,18,25,26].

Effects of MC phase-based RT

The effect of MC phase-based RT on strength measures was reported in six primary research studies. In four studies, participants who engaged in FP-based RT demonstrated superior changes in strength measures, compared to those who engaged in LP-based RT [18,26], regular RT [19], or an undulating RT programme [30]. These strength measures included maximum knee extension, leg, press, bench press and squat jump strength (Table 1). Wikström-Frisén et al. [26] also reported that participants in the control group, who carried out regular RT, gained significantly more strength than the LP-based RT group. In contrast, Sakamaki-Sunaga et al. [27] recorded no significant differences in strength change between their FP-based and LP-based RT groups. Sung and Kim [28] divided their

participants' results into three groups: an underweight group, a group within the normal range BMI score, and an overweight group. This study reported that the underweight participants gained significantly more strength in the LP-based RT group.

The included studies also recorded several other outcomes applicable to women post-ACLR. Firstly, Sung et al. 2014 reported an increase in the quadriceps muscle cell nuclei-to-fibre ratio following FP-based RT only, as compared to the LP-based training group. Secondly, Wikström-Frisén et al. [25] and Vargas-Molina et al. [30] reported increases in power measures such as squat jump and countermovement jump compared to LP-based or undulating RT, respectively. Thirdly, Wikström-Frisén et al. [25] reported that only FP-based RT increased participants' lean body mass. Likewise, Sung et al. [17] reported a superior increase in muscle diameter following FP-based training compared to LP-based RT. Moreover, a pilot study by Vargas-Molina et al. [30] noted that although significant increases in lean body mass were observed for their undulating training group, absolute changes favoured MC phase-based RT.

In addition, Wikström-Frisén et al. [26] reported that participants experienced the LP-based RT program as positive, but participants in LP-based RT or the control group did not. Similarly, Zainab et al. [29] also reported that their FP-based RT group reported reduced dysmenorrhea symptoms and increased quality of life compared to the LP-based RT group.

Other reviews

A systematic review by Thompson et al. [19] aimed to identify and critically appraise studies examining acute and chronic effects of the MC on responses to RT. This review included 17 studies and four original research articles in this scoping review [17,18,25,27]. The authors reported conflicting findings, small participant numbers and methodological issues. Specifically, regarding programme design, Thompson et al. [19] noted a lack of validated menstrual cycle verification methods, and a concern regarding confounding results in studies where participants acted as their own control.

Regarding effects of MC phase-based RT programmes, the systematic review by Thompson et al. [19] concluded that female hormones might affect RT responses & advocated for further experimental studies in the area. A narrative review by Knowles et al. [31] also concluded that women may be able to optimize performance or muscle adaptation by emphasizing RT frequency during the FP of the MC or with combined strength/power training

throughout the cycle. Another narrative review by Randell et al. [32] reported that phase-based RT is a promising area with the potential to maximize training responses in soccer players. The authors advised further research before implementation in a soccer environment due to the logistical challenges of personalizing training loads in squads. In addition, two narrative reviews recommended further research in this area due to the small number of trials and to clarify effects [33,34].

Furthermore, a recently published mechanistic review paper by Oosthuysen et al. [35] discussed the effects of MC phase-based RT on muscle regeneration. Oosthuysen et al. [35] concluded that by unknown mechanisms, progesterone increases protein catabolism during the LP. In addition, Oosthuysen et al. [35] noted that muscle regeneration and strengthening are mostly greater during the FP when oestrogen is present alone without progesterone. Subsequently, Oosthuysen et al. [35] outlined that when women train during the FP when oestrogen is high, superior muscle strengthening results from oestrogen-activated superior satellite cell function. Whereas, when women train during the LP, that progesterone counters this activation of satellite cells. Therefore, Oosthuysen et al. [35] recommend that women plan RT sessions during the FP because progesterone is less active and will not suppress the activation of satellite cells.

Discussion

This review aimed to establish what is known from the literature about MC phase-based RT research for women post-ACLR. Furthermore, it aimed to establish any gaps in this literature. No original studies were found that investigated MC phase-based RT in women with ACL injuries. Six out of eight included primary research studies provided support for FP-based RT [17,18,25,26,29,30].

Participants

The participants included in this review were uninjured and had not undergone ACLR. Therefore, to date, MC phase-based RT programmes have not been investigated in women with ACL injuries. However, most primary studies in this review had participants who were students in their late teens or twenties [17,18,25–27,29] which is in line with the most at-risk female age groups that are affected by ACL injuries [2].

Similarly, participant training status may have implications for research in this area. Three [17,27,28] out of eight primary studies included non-resistance-trained participants, and two did not

note RT status [18,29]. When studies do not use resistance-trained participants, the initial training effect may be more significant than the MC hormonal training response. In an ACLR environment, many sporting women may engage with RT regularly as part of their sporting programme. However, Parsons et al. [36] noted that some women post-ACLR may have reduced familiarity with gym environments due to factors including expectations of weightlifting as masculine. Consequently, there may be a proportion of women who may be more likely to be non-resistance trained on entry to RT programmes or likewise when commencing rehabilitation post-ACLR. Rather than excluding non-resistance-trained women from future trials, participants' allocations could be matched for their initial hormonal and training status to guarantee a homogenous distribution between groups in future research.

Three studies included participants who served as their own control [17,18,27]. With this method, the cross-transfer effects of unilateral training would influence these results [37]. Therefore, future research should investigate participants who do not serve as their own control. Participants not serving as their own control would be especially pertinent in a cohort following ACLR, considering the underlying strength asymmetry between bilateral lower limbs postoperatively. In addition, Wikström-Frisén et al. [25,26] used control groups that distributed OCP and non-OCP users evenly throughout three groups and compared the results across these three groups. These women using the OCP would not have had natural MC hormonal fluctuations. Nevertheless, they were grouped randomly with naturally cycling women, making it challenging to establish the hormonal effects on the RT responses of those in this study with a regular MC taking the OCP [38]. Elliot Sale et al. [39] have provided methodological guidance regarding using OCP groups as control or experimental groups, guiding future research in this area.

It is also worth noting that many of the included experimental studies had low participant numbers (median $n = 20$, minimum $n = 7$, maximum $n = 150$). Women have significant inter- and intra-individual variations in reproductive hormone status, which, combined with low participant numbers, may lead to underpowered studies [39]. Therefore, there is a need for future research in this area to recruit and maintain more significant participant numbers.

RT design

Six out of eight primary studies included RT protocols which guided training frequency, intensity,

volume, progression, and duration of the training period [17,18,25–28]. The guidance is in line with recommendations of a systematic review investigating RT documentation after ACLR [40]. Therefore, the reported training protocols would be considered adequate in detail to apply and relate to a post-ACLR environment. Similarly, the primary research studies included RT programmes between eight- and sixteen weeks. This duration range is in line with recommended RT hypertrophy and strength recovery timeframes post-ACLR, following an initial five to six weeks of postoperative recovery [41]. Therefore, the reported training protocols would also be considered similar in duration to apply and relate to a post-ACLR environment.

In addition to the training detail and duration, participation adherence rates are also pertinent to record to establish between and within group differences in outcome measures related to participants' participation in the RT programme [42]. Furthermore, women post-ACLR must also complete cardiovascular, neuromuscular and agility training as part of their rehabilitation. In line with this, Wikström-Frisén et al. recommended that participants engaging in FP-based RT include these other exercise modalities during training sessions in the LP [25,26].

MC verification methods

One of the challenges in MC phase-based research is establishing the MC phase and status of participants. This challenge is due to incidences of anovulation and LP insufficiency in athletic women [43]. Recent research recommends a three-step gold standard, which includes MC calendar mapping, urinary ovulation prediction kits and blood serum analysis to verify ovarian hormone status [43]. Only one primary study reported using the gold standard three-step method for MC verification [18]. Furthermore, recent research recommends that if participants do not meet the theoretical or stipulated hormonal concentration requirements, researchers should exclude this data from the study [39]. Only Sung et al. [17] and Reis et al. [18] used blood serum analysis post hoc to confirm hormone levels to exclude participants, whilst Wikström-Frisén et al. excluded participants whose MC was longer than 35 days [25,26].

Consequently, as a recent methodological paper recommended, further research is needed in this area to establish the effect of the MC on chronic RT responses using a robust methodology, including gold-standard three-step MC verification and post hoc data exclusion [39]. Regarding the feasibility of tracking the MC in cohorts post-ACLR, it is worth

noting that recent research reported that fifty per cent of elite women athletes in New Zealand record their MC [44]. In addition, rehabilitation post-ACLR is a solitary endeavour, and injured women would not be restricted by the logistical challenges of MC tracking and personalizing training loads in large squads. Therefore, further research to establish the effect of the MC on chronic RT responses, including the incorporation of a robust MC verification methodology, could be conducted in sporting or rehabilitation environments.

Effects of MC phase-based RT

The two included studies that confirmed MC phases by blood serum analysis [17,18] concluded that FP-based RT resulted in superior strength gain than regular and LP-based RT by 20% and 29%. Similarly, the systematic review by Thompson et al. [19] concluded that female hormones may affect RT strength responses, and where possible, to schedule RT in the FP of the MC. Therefore, overall, the results from this review support that the potential positive effects of FP-based RT on strength outcomes are relevant to investigate for women post-ACLR. As previously discussed, persistent impairments in strength are associated with reduced patient outcomes, including reduced function, inferior activity levels and increased reinjury rates [6]. It is also important to note that even minimally superior gains in strength can positively influence recovery post-ACLR [7].

Several other reported results are applicable to women's recovery post-ACLR. Firstly, the higher increases in squat and countermovement jump power measures reported by Wikström-Frisén et al. [25] and Vargas-Molina et al. [30] apply to women post-ACLR. Sports such as netball and skiing, which have high rates of ACL injuries, often include jumping and landing [2]. Therefore women engage in plyometric training to increase their proficiency in these functional movements during ACL rehabilitation. Furthermore, vertical and countermovement hop tests are part of the battery of tests used to clear women back to sport following ACLR [7].

Secondly, Wikström-Frisén et al. [25,26], Sung et al. [17] and Vargas-Molina [30] et al. reported lean body mass changes favoured MC phase-based RT. On this note, Sung et al. [17] reported that women's quadriceps nuclei to cell ratio increased after FP-based training only. As mentioned in the mechanistic review from Oosthuysen et al. [35], these results suggest increased satellite cell recruitment for women who resistance train in the FP of their MC. Increased satellite cell recruitment can lead to several benefits, including reduced muscle atrophy and

improved muscle repair and growth [12,13]. These superior lower limb muscle mass and increase in nuclei-to-cell ratio results are pertinent for women post-ACLR. Disuse atrophy of the quadriceps is common post-ACLR, and recent research has recommended further research into establishing optimal methods to tackle postoperative atrophy [45].

Considering the physical differences noted above, it is also pertinent to consider if women engage in and prefer this type of training. The included studies reported no differences in adherence for different training types. However, Wikström-Frisén et al. [26] reported that more participants experienced FP-based RT as positive, compared to regular or LP-based training [26], indicating that FP-based training may be favourable for women. It is unknown whether this noted preference for FP-based training may relate to MC phase differences in mood or motivation. Mood or motivation for training was not reported or monitored in any of the included studies despite recent research reporting that hormonal fluctuations can affect both factors [46,47]. Motivation for training is essential in a rehabilitation environment [42], and for athletes post-ACLR, higher motivation during rehabilitation is associated with returning to pre-injury sport [48]. Therefore, there is a role for future research to investigate this topic and explore the rationale for participants' preference for FP-based RT, which is also relevant for women post-ACLR.

Likewise, Zainab et al. [29] reported a superior reduction in pain symptoms for their FP-based RT participant group with dysmenorrhea. The impact of RT on pain symptoms is also applicable and relevant to women post-ACLR, as pain symptoms may affect their ability to engage in RT following ACLR.

Limitations

This review is the first to consider the methodologies of MC phase-based RT and identify an opportunity for future research in a population group that needs efficient and effective RT approaches. There are several limitations to consider. The researchers are English-speaking and thus this scoping review is limited to English language research only. Furthermore, this scoping review is limited to the available research, including several studies with small sample sizes and methodological issues. In addition, this review did not undertake any formal methodological quality assessment. Because the aim was to provide a general overview of existing literature, there is no synthesized result or answer to any question. Furthermore, this scoping review is at risk of bias from different sources, including selection bias [21]. However, the complete search strategy,

including the iterations, was all documented to acknowledge and mitigate this risk of selection bias. Similarly, as the Open Science Framework does not permit modifications to registered protocols, the changes made to this study may not be apparent to other researchers. However all protocol changes were noted in the Material and Methods section to ensure transparency and reliability.

Conclusion

This scoping review provides an overview of current literature relating MC phase-based RT for women, providing implications for future research for post-ACL rehabilitation. To date, there are no current published studies investigating the effects of MC phase-based RT following ACLR. This review included eight original research studies, six supporting FP-based RT to enhance training responses. The included studies described RT protocols and results relevant and applicable to women post-ACLR. Specifically, the studies that confirmed MC phases by blood serum analysis concluded that FP-based RT resulted in superior strength gain than regular and LP-based RT. In addition, studies reported superior training results for FP-based RT, including increased lean body mass, nuclei-to-cell ratio, superior power measures, participant preference, quality of life, and symptom improvement measures. These results support that these described FP-based training protocols may influence responses relevant to women post-ACLR. Therefore, this review also supports future research which examines how FP-based RT affects naturally cycling women following ACLR. Researchers should conduct all future research in line with up-to-date methodological recommendations.

Acknowledgements

The authors wish to express their sincere appreciation for the invaluable contribution of Michael Fauchelle, librarian, who collaborated with them in formulating a robust search strategy for the literature review.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by The New Zealand Manipulative Physiotherapists Association (NZMPA) Scholarship 2020. It was also supported by the Accident Compensation Corporation (ACC) who have provided funding for the primary author's PhD studies as part of her continuing professional development plan.

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References

- Chinurum JN, Ogunjimi LO, O'Neill CB. Gender and sports in contemporary society. *J Educ.* 2014; 4(7):25. doi:10.5901/jesr.2014.v4n7p25.
- Sutherland K, Clatworthy M, Fulcher M, et al. Marked increase in the incidence of anterior cruciate ligament reconstructions in young females in New Zealand. *ANZ J Surg.* 2019;89(9):1151–1155. doi:10.1111/ans.15404.
- Paudel YR, Sommerfeldt M, Voaklander D. Increasing incidence of anterior cruciate ligament reconstruction: a 17-year population-based study. *Knee Surg Sports Traumatol Arthrosc.* 2023;31(1): 248–255. doi:10.1007/s00167-022-07093-1.
- Van Melick N, Van Cingel RE, Brooijmans F, et al. Evidence-based clinical practice update: practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus. *Br J Sports Med.* 2016;50(24): 1506–1515. doi:10.1136/bjsports-2015-095898.
- Maguire K, Sugimoto D, Micheli LJ, et al. Recovery after ACL reconstruction in male versus female adolescents: a matched, sex-based cohort analysis of 543 patients. *Orthop J Sports Med.* 2021;9(11): 232596712111054804. doi:10.1177/232596712111054804.
- Cristiani R, Mikkelsen C, Edman G, et al. Age, gender, quadriceps strength and hop test performance are the most important factors affecting the achievement of a patient-acceptable symptom state after ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2020;28(2):369–380. doi:10.1007/s00167-019-05576-2.
- Grindem H, Snyder-Mackler L, Moksnes H, et al. Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *Br J Sports Med.* 2016;50(13): 804–808. doi:10.1136/bjsports-2016-096031.
- Tan SH, Lau BP, Khin LW, et al. The importance of patient sex in the outcomes of anterior cruciate ligament reconstructions: a systematic review and meta-analysis. *Am J Sports Med.* 2016;44(1):242–254. doi:10.1177/0363546515573008.
- Hawley JA, Burke LM, Phillips SM, et al. Nutritional modulation of training-induced skeletal muscle adaptations. *J Appl Physiol.* 2011;110(3): 834–845. doi:10.1152/jappphysiol.00949.2010.
- Lamon S, Morabito A, Arentson-Lantz E, et al. The effect of acute sleep deprivation on skeletal muscle protein synthesis and the hormonal environment. *Physiol Rep.* 2021;9(1):e14660. doi:10.14814/phy2.14660.
- Douglas J, Pearson S, Ross A, et al. Chronic adaptations to eccentric training: a systematic review. *Sports Med.* 2017;47(5):917–941. doi:10.1007/s40279-016-0628-4.
- Lowe DA, Baltgalvis KA, Greising SM. Mechanisms behind estrogen's beneficial effect on muscle strength in females. *Exerc Sport Sci Rev.* 2010;38(2): 61–67. doi:10.1097/JES.0b013e3181d496bc.
- Strehlow K, Rotter S, Wassmann S, et al. Modulation of antioxidant enzyme expression and function by estrogen. *Circ Res.* 2003;93(2):170–177. doi:10.1161/01.RES.0000082334.17947.11.
- Enns D, Tiidus P. The influence of estrogen on skeletal muscle: sex matters. *Sports Med.* 2010;40(1):41–58. doi:10.2165/11319760-000000000-00000.
- Kriengsinyos W, Wykes LJ, Goonewardene LA, et al. Phase of menstrual cycle affects lysine requirement in healthy women. *Am J Physiol Endocrinol Metab.* 2004;287(3):E489–E496. doi:10.1152/ajpendo.00262.2003.
- Albert K, Pruessner J, Newhouse P. Estradiol levels modulate brain activity and negative responses to psychosocial stress across the menstrual cycle. *Psychoneuroendocrinology.* 2015;59:14–24. doi:10.1016/j.psyneuen.2015.04.022.
- Sung E, Han A, Hinrichs T, et al. Effects of follicular versus luteal phase-based strength training in young women. *Springerplus.* 2014;3(1):668. doi:10.1186/2193-1801-3-668.
- Reis E, Frick U, Schmidbleicher D. Frequency variations of strength training sessions triggered by the phases of the menstrual cycle. *Int J Sports Med.* 1995;16(8):545–550. doi:10.1055/s-2007-973052.
- Thompson B, Almarjawi A, Sculley D, et al. The effect of the menstrual cycle and oral contraceptives on acute responses and chronic adaptations to resistance training: a systematic review of the literature. *Sports Med.* 2020;50(1):171–185. doi:10.1007/s40279-019-01219-1.
- Mays N, Roberts E, Popay J. Studying the organisation and delivery of health services: research methods. In: Fulop N, Allen P, Clarke A, Black N, editors. *Synthesising research evidence.* London: Routledge; 2001. p.188–220.
- Tricco A, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med.* 2018;169(7):467–473. doi:10.7326/M18-0850.
- Peters MDJ, Marnie C, Colquhoun H, et al. Scoping reviews: reinforcing and advancing the methodology and application. *Syst Rev.* 2021;10(1):263–263. doi:10.1186/s13643-021-01821-3.
- Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol.* 2005;8(1):19–32. doi:10.1080/1364557032000119616.
- O'Loughlin E, Reid D, Sims S. Is there a role for menstrual cycle phased resistance training programmes for women post anterior cruciate ligament reconstruction? A scoping review protocol. *Phys Ther Rev.* 2022;27(3):176–180. doi:10.1080/10833196.2021.2017613.
- Wikström-Frisén L, Boraxbekk CJ, Henriksson-Larsén K. Effects on power, strength and lean body mass of menstrual/oral contraceptive cycle based resistance training. *J Sports Med Phys Fitness.* 2017; 57(1–2):43–52. doi:10.23736/S0022-4707.16.05848-5.
- Wikström-Frisén L, Boraxbekk CJ, Larsén K. Increasing training load without risking the female athlete triad: menstrual cycle based periodized training may be an answer? *J Sports Med Phys Fitness.* 2017;57(11):1519–1525. doi:10.23736/S0022-4707.16.06444-6.

27. Sakamaki-Sunaga M, Min S, Kamemoto K, et al. Effects of menstrual phase-dependent resistance training frequency on muscular hypertrophy and strength. *J Strength Cond Res.* 2016;30(6):1727–1734. doi:10.1519/JSC.0000000000001250.
28. Sung ES, Kim JH. The resistance training effects of different weight level during menstrual cycle in female. *J Exerc Rehabil.* 2019;15(2):249–253. doi:10.12965/jer.193808.024.
29. Zainab S, Nithyashree P, Jumanah R, et al. A study to compare the effectiveness of core strengthening exercises for phase I and phase II of menstrual cycle in primary dysmenorrhea subjects. *Biomedicine.* 2021;41(2):315–317. doi:10.51248/v41i2.804.
30. Vargas-Molina S, Petro JL, Romance R, et al. Menstrual cycle-based undulating periodized program effects on body composition and strength in trained women: a pilot study. *Sci Sports.* 2022; 37(8):753–761. doi:10.1016/j.scispo.2021.11.003.
31. Knowles OE, Aisbett B, Main LC, et al. Resistance training and skeletal muscle protein metabolism in eumenorrheic females: implications for researchers and practitioners. *Sports Med.* 2019;49(11):1637–1650. doi:10.1007/s40279-019-01132-7.
32. Randell RK, Clifford T, Drust B, et al. Physiological characteristics of female soccer players and health and performance considerations: a narrative review. *Sports Med.* 2021;51(7):1377–1399. doi:10.1007/s40279-021-01458-1.
33. Hansen M, Langberg H, Holm L, et al. Effect of administration of oral contraceptives on the synthesis and breakdown of myofibrillar proteins in young women. *Scand J Med Sci Sports.* 2011;21(1):62–72. doi:10.1111/j.1600-0838.2009.01002.x.
34. Gharahdaghi N, Phillips BE, Szewczyk NJ, et al. Links between testosterone, oestrogen, and the growth hormone/insulin-like growth factor axis and resistance exercise muscle adaptations. *Front Physiol.* 2020;11:621226. doi:10.3389/fphys.2020.621226.
35. Oosthuysen T, Strauss JA, Hackney AC. Understanding the female athlete: molecular mechanisms underpinning menstrual phase differences in exercise metabolism. *Eur J Appl Physiol.* 2023; 123(3):423–450. doi:10.1007/s00421-022-05090-3.
36. Parsons JL, Coen SE, Bekker S. Anterior cruciate ligament injury: towards a gendered environmental approach. *Br J Sports Med.* 2021;55(17):984–990. doi:10.1136/bjsports-2020-103173.
37. Green LA, Gabriel DA. The cross education of strength and skill following unilateral strength training in the upper and lower limbs. *J Neurophysiol.* 2018;120(2):468–479. doi:10.1152/jn.00116.2018.
38. Sims ST, Heather AK. Myths and methodologies: reducing scientific design ambiguity in studies comparing sexes and/or menstrual cycle phases. *Exp Physiol.* 2018;103(10):1309–1317. doi:10.1113/EP086797.
39. Elliott-Sale KJ, Minahan CL, de Jonge X, et al. 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 Med.* 2021;51(5):843–861. doi:10.1007/s40279-021-01435-8.
40. Augustsson J. Documentation of strength training for research purposes after ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(8): 1849–1855. doi:10.1007/s00167-012-2167-3.
41. Buckthorpe M, La Rosa G, Villa FD. Restoring knee extensor strength after anterior cruciate ligament reconstruction: a clinical commentary. *Intl J Sports Phys Ther.* 2019;14(1):159–172. doi:10.26603/ijsp20190159.
42. Walker A, Hing W, Lorimer A. The influence, barriers to and facilitators of anterior cruciate ligament rehabilitation adherence and participation: a scoping review. *Sports Med Open.* 2020;6(1):32. doi:10.1186/s40798-020-00258-7.
43. Schaumberg MA, Jenkins DG, Janse de Jonge XA, et al. Three-step method for menstrual and oral contraceptive cycle verification. *J Sci Med Sport.* 2017;20(11):965–969. doi:10.1016/j.jsams.2016.08.013.
44. Heather AK, Thorpe H, Ogilvie M, et al. 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. *Front Sports Act Living.* 2021;3:601420. doi:10.3389/fspor.2021.601420.
45. Thomas AC, Wojtys EM, Brandon C, et al. Muscle atrophy contributes to quadriceps weakness after anterior cruciate ligament reconstruction. *J Sci Med Sport.* 2016;19(1):7–11. doi:10.1016/j.jsams.2014.12.009.
46. Prado RCR, Silveira R, Kilpatrick MW, et al. The effect of menstrual cycle and exercise intensity on psychological and physiological responses in healthy eumenorrheic women. *Physiol Behav.* 2021;232: 113290. doi:10.1016/j.physbeh.2020.113290.
47. Cook CJ, Kilduff LP, Crewther BT. Basal and stress-induced salivary testosterone variation across the menstrual cycle and linkage to motivation and muscle power. *Scand J Med Sci Sports.* 2018;28(4): 1345–1353. doi:10.1111/sms.13041.
48. Sonesson S, Kvist J, Ardern C, et al. Psychological factors are important to return to pre-injury sport activity after anterior cruciate ligament reconstruction: expect and motivate to satisfy. *Knee Surg Sports Traumatol Arthrosc.* 2017;25(5):1375–1384. doi:10.1007/s00167-016-4294-8.