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A reveiw on recovery after endurance and resistance exercise among eumenorrheic women

Bachelor's thesis in Bevegelsesvitenskap
Supervisor: Dionne Noordhof
May 2023

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Abstract

Purpose: To this day there is a lack of sport and exercise science research including female athletes. Therefore, it is relevant to research the influence the menstrual cycle (MC) has on sport and exercise. The aim of this literature review is to assess the effect the MC has on recovery after exercise. **Method:** A digital literature search was conducted using PubMed, SPORTDiscuss, SCOPUS and Google scholar. Different terms for the MC, exercise and recovery were combined and used. Studies had to compare parts of the two different menstrual cycle phases (MCP), include eumenorrheic women and use blood markers to assess the recovery status. **Results:** four studies were included for endurance and resistance exercise each. Three of four endurance exercise studies observed a significant effect of the MC on recovery after endurance. The last study found no significant effect of the MCP on recovery after endurance exercise. Initially none of the four studies assessing recovery after resistance exercise observed any significant effect of the MCP. **Conclusion:** It seems to be bigger effect of the MC on recovery after endurance exercise compared to resistance exercise. There is still need for more research on this subject with more extensive studies.

Bakgrunn: Til den dag i dag er det mangel på kvinner inkludert i forskning relatert til idrett og trening. Det vil derfor være relevant å undersøke effekten menstruasjons syklusen (MS) har på idrett og trening. Målet med denne studien vil være å undersøke effekten MS har på restitusjon etter trening. **Metode:** Et digitalt litteratursøk ble gjennomført på PubMed, SPORTDiscuss, SCOPUS og Google scholar. Ulike synonymer for MS, trening og restitusjon ble kombinert og brukt i søket. Studiene måtte sammenligne deler av de to ulike menstruasjons syklus fasene (MSF), inkludere normalt menstruerende kvinner og bruke blodvariabler for å undersøke restitusjons statusen. **Resultat:** Fire studier ble inkludert for hver av utholdenhet og styrke trening. Tre av de fire utholdenhetsstudiene observerte en signifikant effekt av MS på restitusjonen etter utholdenhetstreningen. Den siste studien som studerte restitusjon etter utholdenhets trening fant ingen signifikant effekt av MS. I utgangspunktet var det ingen funn på effekten av MS på restitusjon etter styrke trening for noen av de fire studiene. **Konklusjon:** MS ser ut til å ha en større effekt på restitusjonen etter utholdenhetstrening i motsetning til styrketrening. Det er likevel behov for mer forskning på dette emnet med mer omfattende studier.

Keywords: resistance exercise, endurance exercise, exercise recovery, follicular phase, luteal phase, sex hormones, blood markers.

1 Introduction

Sports have for a long time been seen as a male dominated field, where women were considered intruders of the field. Because of this it was a problem with inclusion and arrangements of sports events for female athletes in sport thru the 20^{th} century (1). For the last five decades a positive development is seen in the inclusion of women. In the 2024 summer Olympics the gender distribution for the athletes will be equal, compared to 1972 when the female participants constituted 14,2% (1,2). Despite there being an equal participation in sports and exercise, females are still underrepresented in sport and exercise science research (3). The differences in the male and female anatomy and physiology may influence the performance and recovery in sport and exercise for the two genders. Therefore, it would be interesting to expand the research field on female sport and athletes, to shed the light on how the female body may influence females' performance and recovery ability.

The menstrual cycle (MC) is a biological process that most of the female population experiences in their life. The female sex hormones estradiol, which is a type of estrogen, and progesterone fluctuate throughout the MC. The MC has a median length of 28 days and can be divided into two phases. The follicular phase (FP) day 1-14, starts with the day of onset menstruation and ends when the ovulation begins (4). The luteal phase (LP), day 15-28 starts with the ovulation and lasts to the next menstruation (4). Different parts of the two phases can also be defined as the early- mid and late follicular or luteal phase. The ovulation is set in the middle of the MC and can be referred to as an own phase; ovulatory phase (OP). A figure of the MC is to be found in figure 1.

In sport and exercise, recovery is an important factor to get the adaptation from the training session, and to be able to perform on the best possible level (5). Recovery is an umbrella term that involves different methods of recovery. Examples of methods to recover to an optimally physiological and psychological level are sleep and psychological relaxation technique. To determine if the recovery is optimal one can measure it in several different ways. One can look at fatigue, muscle soreness, cardiorespiratory and blood markers, among others. Blood markers can be strong biomarkers when assessing the state of recovery and the balance between exercise and recovery (6). Different blood markers can be used to assess recovery, such as Creatin Kinase

(CK) and Interlaukin-6 (IL-6). One of the challenges when assessing blood markers is that one single marker is not strong enough to define a physiological state as broad as recovery (6). Based on this, it is relevant to make a literature review including numerous blood markers to be able to assess and compare different results, to either strengthen or conflict the observations. It is also interesting to make a review on this subject including both resistance and endurance studies, to see if the exercise methods get affected differently by the MC. This review will therefore assess what influence the menstrual cycle phases (MCP) have on recovery after endurance and resistance exercise among eumenorrheic women.

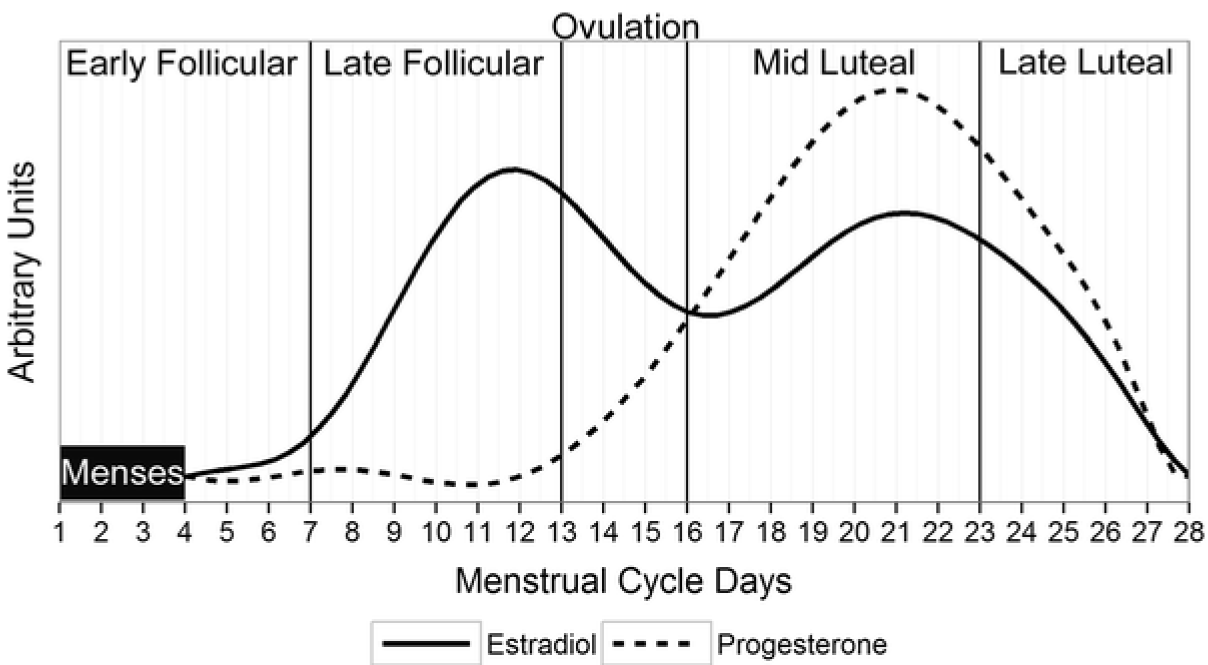

Figure 1: Fluctuations of the female sex hormones estrogen and progesterone throughout the MC (7).

2 Methods

2.1 Literature search

In the period February 8th to March 13th, 2023, a digital literature search was conducted using the databases PubMed, SPORTDiscuss, SCOPUS and Google scholar. The search terms used were "menstrual cycle", "period", "menstruation"," menses", "muscle damage", "follicular phase", "luteal phase", "recovery", "menstrual phases", "eccentric exercise", and "recovery after exercise", as well as the sentences "effect of menstrual cycle on recovery" and "menstrual cycle affects recovery”. The search terms were used in different combinations using “AND” and “OR”. Synonyms were combined using “OR”, and “AND” was used to combine the different exercise and recovery terms with the MC terms.

2.2 Study selection

For the studies to be included in this review, they had to be in English language, peer-reviewed, full text available and had to contain the search terms in the keywords, abstract or title. In addition to using these inclusion criteria’s, the outcomes from the searches were manually assessed, to which they were to be included or not. Studies were excluded if they did not fulfill the following criteria: 1) comparison between parts of the two different MCP (e.g., early-, mid- or late follicular and early- or mid luteal phase); 2) inclusion of a eumenorrheic women group; 3) use of blood markers in the assessment of the recovery status after exercise. Studies including a male or amenorrheic group were included if there was a comparison between at least two of the different MCP, within the eumenorrheic group. This resulted in a final selection of 8 studies.

3 Results

3.1 Endurance exercise

Four studies researching the MC effect on recovery after endurance exercise were included and compared. Their characteristics are included in Table 1. All the studies tested their subjects in the MFP and MLP. The testing included running sessions on a treadmill. The four studies used some different blood markers to assess the state of recovery, including CK, IL-6, blood lactate and testosterone.

Table 1: Characteristics and results of the included endurance exercise studies

Author(s), year	**Participants**	**Protocol**	**Main result**
Williams et al. (2015)	*No:* 10 *Age*: 21±1 Minimum aerobic training volume of 3-5 d/w, 45-120 minutes per session.	60 min treadmill run at 60-65% VO_{2max}. CK and CK-MB concentration immediately after, 30 min and 24h post exercise in MFP and MLP	CK concentration were significantly higher 24 hours post-exercise in MFP than MLP. The CK concentration were significantly higher 30 minutes and 24 hours post-exercise compared to before. The CK-MB concentration did not change in a significant way.
McCracken et al. (1994)	*No:* 9 *Age:* 25±7 Physically active subjects	Treadmill run with incremental protocol; min 1-10 at 35% of VO_{2max}, min 11-20 at 60% VO_{2max}, min 21-30 at 75% VO_{2max} and after min 30 at 90% VO_{2max}. Then exercise till exhaustion. Blood lactate concentration at 3- and 30 min post exercise in MFP and MLP	Recovery blood lactate concentration were significantly lower in MLP than MFP both 3- and 30-minutes post exercise.
O'Leary et al. (2013)	*No:* 10 *Age:* 20±2.2 Recreationally trained	Two 60 min treadmill runs at 65-70% of VO_{2max}. Testosterone response pre, immediately after and 30 min post exercise in MFP and MLP	Non-significant difference on testosterone response at recovery, in MFP and MLP.
Hackney et al. (2019)	*No:* 8 *Age:* 25 ± 4 Minimum of 4-5 exercise sessions per week, with 45-120 minutes of aerobic exercise within each of those sessions/days.	90-minute run on treadmill, at 70% of VO_{2max} CK and IL-6 concentration pre, immediately after, 24h and 72h post exercise	The CK concentration was significantly higher in MFP than MLP at 24 h and 72 h post exercise. IL-6 was significantly higher in MFP than MLP immediately after exercise, 24 h and 72 h post exercise.

CK = creatin kinase, CK-MB = creatin kinase-MB, IL-6 = interleukin-6, MFP = mid-follicular phase, MLP = mid-luteal phase

Three of four studies observed a significant difference between the MFP and MLP for three of the blood markers (CK, IL-6 and blood lactate). Williams et al. (8) observed a greater elevation of the CK concentration at 30-minutes and 24-hours post exercise in the MFP than the MLP, and Hackney et al. (9) observed the same result for 24-hours and 72-hours post exercise. Hackney et al. (9) also observed significant higher concentration of IL-6 at all of the three measuring times after exercise, in the MFP compared to the MLP. McCracken et al. (10) observed significantly higher concentration in MFP than MLP at both 3-and 30-minutes after exercise, when measuring the blood lactate. All these studies gave results that showed that the markers were significantly higher in the MFP than the MLP. The results also showed that the markers were elevated for a longer time in the three studies, when looking at the different measuring times post exercise.

One study researched the recovery testosterone concentration. O'Leary et al. (11) observed no significant interaction for neither of the two MCP and the testosterone concentration at both immediately after and 30 minutes into recovery. Williams et al. (8) also measured CK-MB, in addition to CK. The CK-MB concentration did not change in a significant way for neither of the measuring times or the MCP.

3.2 Resistance exercise

Four studies researching the effect of MCP on recovery after resistance exercise was included and compared in this review. Their characteristics are included in Table 2. All four studies performed their testing in the EFP (12–15), in addition three of the studies tested in MLP (13–15), while two tested in the LFP (14,15) and one study tested in the OP (12).

Table 2: Characteristics and results of the included resistance exercise studies

Author, year	**Participants and characteristics**	**Protocol**	**Main result**
Romero-Parra et al. (2020)	*No:* 19 *Age:* 26.6 ± 5.9 Well-trained; resistance-trained	10 sets of 10 reps of plate-loaded barbell parallel back squats, 60% of 1RM. 2 min of rest between sets CK, myoglobin, LDH, CRP, TNF-α, IL-6, AST, ALT concentration at 2h-, 24h- and 48h post exercise in EFP, LFP and MLP.	No significant effect of MCP on CK-activity No significant effect of MCP in myoglobin, LDH, AST, IL-6, TNF-α and CRP Interaction between time and MCP in IL-6: 2h post exercise concentration was higher than both pre exercise, 24h and 48h post exercise in MLP only
Funaki et al. (2022)	*No:* 24 *Age:* EFP group; 26.9 ± 6.7 and MLP group; 26.2 ± 6.3 Untrained; no resistance training, nor vigorous exercises for at least 6 months before the study	10 sets of 6 reps of maximal voluntary isokinetic eccentric exercise of elbow flexors 2 min of rest between sets CK concentration and leukocyte count at 4h-, 48h-, and 96 h post exercise in EFP and MLP.	No significant effect of MCP on CK-concenctration **Neutrophil count (pre- 4h post):** Percent change is lower in MLP than in EFP. No correlation between estradiol and change in neutrophil count in EFP and MLP No correlation between progesterone and change in neutrophil count in EFP. Significant negative correlation between progesterone and change in neutrophil counts in MLP
Sipavičienė et al. (2013)	*No:* 18 *Age:* 20.2 ± 1.7 Healthy and physically active	100 maximum drop jumps from 0.75 m height, with 20s intervals. CK concentration at pre- and 24h post exercise in EFP and OP.	CK increased to a similar level in both EFP and OP, no significant difference between the phases
Oosthuyse and Bosch (2017)	*No:* 15 *Age:* 21.7±2.4 Sedentary	20-minute run on treadmill, at 9 km/h at -10% gradient CK concentration pre-, immediately after, 24h, 48h and 72h post exercise in EFP, LFP and MLP.	Initially no significant effect of MCP on CK concentration After omitting an outlier from LFP, a negative correlation between both 24h and 48h post exercise CK concentration and estrogen

1RM = 1 repetition maximum, CK= creatine kinase, LDH = lactate dehydrogenase, CPR= C reactive protein, TNF-α= tumoral necrosis factor α, AST= aspartate aminotransferase, ALT= alanine aminotransaminase, EFP= early follicular phase, LFP= late follicular phase, MLP= mid luteal phase, OP= ovulatory phase

All four studies assessed the CK-activity as a marker of recovery after resistance exercise. Initially none of the studies observed any significant effect of the MCP. It was only after omitting an outlier for LFP, that Oosthuyse and Bosch (15) observed an negative correlation between 24h and 48h post exercise CK concentration and the estrogen concentration.

Funaki et al (13) was the only study assessing the leukocyte count. They observed no significant interaction between the MCP and the recovery time after exercise. In addition, they presented a significant negative correlation in MLP, between progesterone and the percentage change in neutrophil counts from pre exercise to 4h post exercise. Other blood markers of muscle damage and inflammation, was used by Romero-Parra (14) to assess the recovery after exercise. For neither of the blood markers no significant effect of MCP was observed. Although no effect of MCP was observed in IL-6, the 2h post exercise concentration was higher than both the pre-exercise, 24h and 48h post exercise concentration in MLP only, this indicates an interaction between MCP and time for IL-6.

4 Discussion

The purpose of this review was to assess the influence of the MCP on recovery after exercise. Eights studies were included, four of which researched endurance exercise (8–11) and four of which researched resistance exercise (12–15). Three out of four of the endurance exercise studies observed a significant effect of the MC on recovery, when looking at CK, IL-6 and blood lactate (8–10). The blood markers in the MFP were greater than the blood markers in the MLP. The last study observed no significant effect of the MC on recovery when assessing the recovery testosterone concentration (11). There were also no significant change in the blood markers of the CK-MB, between the MCP (8). Neither of the four resistance exercise studies observed an effect of MCP on CK-activity, neutrophil counts nor other blood markers. One out of the four studies observed a negative correlation between the CK concentration and estrogen (15), in addition one out of the four studies observed a negative correlation between the percentage change in neutrophil counts and progesterone (13). Lastly, an interaction between MCP and time was observed for IL-6 in one of the studies (14). The effect of MCP on recovery is shown to be different between endurance and resistance exercise. Based on the results from the different studies, the MCP have a greater effect on the recovery markers after endurance exercise.

4.1 Effect of the menstrual cycle on recovery after endurance exercise

Two of the included studies assessing recovery after endurance exercise researched CK as a blood marker. CK is an enzyme found in skeletal muscles that gets released into the blood stream when the muscle, hearth or brain tissue is damaged. This will lead to elevated CK levels. CK-MB is found almost exclusively in the heart muscle and the concentration in the blood gets elevated when the heart experiences increased strain (16,17). The female participants included in the Williams et al. (8) and Hackney et al. (9) studies, were all tested in both MFP and MLP. Williams et al. (8) defined MFP as day 7 after the onset menses, while Hackney et al. (9) defined it as day 8 after onset menses. Both studies defined MLP as day 23 after onset menses. When looking at figure 1 (7) this makes MFP the testing phase with low female sex hormone and MLP with high female sex hormone levels. The results of both Williams et al. (8) and Hackney et al. (9) shows that the recovery time from endurance exercise is influenced by MCP. Both studies observed significantly higher CK values in MFP than MLP at 24 hours post exercise, and in Hackney et al. (9) also 72 hours post exercise. Based on the information on the fluctuations in female sex hormones throughout the MC, this indicates that the estrogen and progesterone levels influence muscle damage after endurance exercise. When the levels of female sex hormones are low, as in MFP, CK values are higher, and stay higher for a longer time after the exercise bout. This indicates that the muscle damage becomes more severe, and that the recovery process will take longer when exercising in MFP than MLP.

Williams et al. (8) did not observe any significant change in the CK-MB markers, despite the great elevated CK markers. This indicates that the damage from the exercise came mainly from the skeletal muscle, and not from the heart muscle. Compared with another study researching the CK-MB values after endurance exercise, the results when comparing pre and post exercise from Williams et al. (8) may not be significant because of the length of the treadmill session. The comparative study found significantly elevated levels in CK-MB after ended endurance exercise that lasted for 334 ± 42 minutes (18). One day after this session the CK-MB values was 15,24 ng·mL-1, compared to the 5,6-5,7 ng·mL-1 at 24 hours after the 60 minutes endurance session in the Williams et al.(8) study. This indicates that one may see a significantly elevated level of CK-

MB after endurance exercise, if the length of the exercise is longer than 60 minutes, and that the hearth therefor would experience a higher amount of strain.

Two of the studies that observed a significant effect of the MC were assessing IL-6 and blood lactate (9,10). IL-6 plays a key role in the inflammation process after tissue injuries, by responding to the acute phase and stimulating hematopoiesis and the immune reactions (19). IL-6 values will therefore be elevated when in the recovery phase after exercise, because the body has experienced increased amount of physical strain. Blood lactate works as an indirect marker on fatigue (20). The concentration on blood lactate does not increase until the amount that is produced overgoes the amount that gets removed in the body (20). The results from Hackney et al. (9) shows that the IL-6 values in MFP were significantly higher in all of the three measuring times after the exercise session, than the MLP values. In the same way as the CK values, the IL-6 values increases significantly more when the female sex hormone levels are high and stays high for å longer time after the ended session. McCracken et al. assessed the changes in blood lactate in MFP (6-9 days after menses) and MLP (6-9 days after ovulation) after endurance exercise. In the McCracken et al. study lactate levels were measured at a higher level in the MFP than MLP at both measuring times. Based on the information from the three blood markers a connection can be drawn between the low female sex hormone levels in the MFP and the high levels of both CK, IL-6 and blood lactate. This indicates that the recovery time is longer in the MFP than the MLP, and that recovery is more required after endurance exercise in the MFP.

The last blood marker which was assessed were testosterone. Testosterone is a sex hormone and is known to have a higher concentration in males then females (11). Regarding recovery after exercise testosterone has an impact on the muscle tissue growth, recovery and remodeling of the muscles (21). In the study by O'Leary et al. (11) the results showed that the testosterone concentration increased at the measuring immediately after the exercise, for then to drop back to normal values again 30 minutes post exercise. This happened in both the MFP (day 7 of the cycle) and MLP (day 20 of the cycle) session. This indicates that the female sex hormone levels do not influence the testosterone levels on these specific phases of the MC, and that there is no significant difference in the findings between the two phases. However, it is assumed that the testosterone levels in women will peak when they are ovulating (22). Bui et al. (22) have assessed the fluctuation of testosterone throughout the MC. Their results showed that at a group level the testosterone level were significantly elevated around the women's ovulation, compared to the follicular and luteal phase. However Bui er al. (22) also observed that not all of the women showed significantly higher testosterone levels around ovulation, when researching at an individual level. O'Leary et al. (11) didn't find significant elevated testosterone levels when assessing the MC, despite the assumption that the testosterone will be effected by the MC. This may be because O'Leary et al. (11) tested the subjects in the MFP and MLP, while the testosterone is shown to be affected by the MC when tested around the ovulation. The small sample size of the O'Leary et al. (11) study may also be an factor that influence the non-significant elevated testosterone levels in the subjects. This is based on the results from Bui et al. (22) which indicates that there are individual differences in testosterone levels throughout the cycle. If the sample size of the O'Leary et al. (11) study had been lager, the results may had been different. The fact that the elevated level of testosterone drops back to normal after only 30 minutes may indicate that the hormone doesn't have that much influence in the recovery in women. It is stated that the female body produce 20 to 30 times less testosterone than men, and that the testosterone concentration in the blood is 10 times lower in women than men (11). Based on this it is reasonable to assume that the role testosterone has on recovery after exercise is not as significant for women as in may be for men.

4.2 Effect of the menstrual cycle on recovery after resistance exercise

All four of the resistance exercise studies, used CK as a blood marker to assess the recovery after resistance exercise. Neither of the included studies initially found any significant effect of MCP on the CK concentration. Although, when omitting an outlier from LFP, Oosthuyse and Bosch (15) observed an negative correlation between both 24h and 48h post exercise CK concentration, relative to the pre-exercise concentration, and the estrogen concentration. This indicates that an increase in estrogen concentration, will lead to a decrease in the CK concentration. Contrary to this, Markofski and Braun (23) observed an interaction between time and MCP, where the 96h post exercise CK concentration was significantly higher in the follicular phase than the luteal phase. I addition to being contrary to the results from Oosthuyse and Bosch (15), was these results also contrary to Markofski and Braun´s own hypothesizes (23). Due to these contradictory results, in addition to the small sample sizes included in the resistance exercise studies and the fact that only one out of the four resistance exercise studies observed any significant effect of MCP, makes it difficult to conclude whether the MCP has an actual effect on the CK concentration after resistance exercise.

Funaki et al. (13) was the only one, out of the four included studies, which assessed the leukocyte count as a marker of muscle damage after resistance exercise. Leukocytes, also called the white blood cells, is small cells which circulates in the blood. As a part of the immune system, the white blood cells travel to injured sites in the body to help fight infection (24). Strenuous exercise is known to cause tissue damage in the muscles, therefor an elevated leukocyte count is expected after exercise. Funaki et al. (13) tested the participants during their EFP and MLP, defining the phases as day 4,7 ± 2 and day 24,2 ± 3,4 after onset menses, respectively. Funaki et al. (13) observed no difference in the leucocyte count after exercise between the two phases. There are five types of leukocytes, one of which is neutrophils (24). In their study, Funaki et al. (13) observed a negative correlation between progesterone concentration and the percentage change in neutrophil counts, from pre exercise to 4h post exercise, in MLP. This negative correlation indicates that a higher concentration of sex hormones will lead to a lower concentration of neutrophils. Funaki et al. states that they seem to be the first study using leukocytes in assessing the recovery after exercise, in women across the MC (13).

Only one of the resistance exercise studies included, researched a few other blood markers of muscle damage an inflammation as markers of recovery after exercise. The study included blood markers such as hemoglobin, lactate dehydrogenase (LDH), interleukin-6 (IL-6), tumoral necrosis factor- α (TNF- α), c-reactive protein (CRP), Alanine aminotransaminase (ALT) and aspartate aminotransferase (AST). Romero-Parra et al. (14) observed no significant effect of MCP on neither of these blood markers. Jilma et al. (25) researched the effect of the MC on different blood marker concentration, in which Il-6 and CRP was two of them. Similar to the results from Romero-Parra et al. (14), Jilma et al. (25) observed no changes in the IL-6 concentration throughout the MC. Contrary to the findings from Romero-Parra et al. (14), Jilma et al. (25) observed that CRP may be dependent on the MC, where the increase in CRP correlated with the increase in progesterone. In addition, Romero-Parra et al. (14) observed an significant interaction between time and MCP in the IL-6 concentration, whereas the 2h post exercise concentration was higher than both the pre-exercise, 24h and 48h post exercise concentrations, in MLP only. Although Jilma et al.(25) does not use the mentioned blood markers to assess recovery after exercise, a clear representation of how the initial concentrations of the blood markers act throughout the MC is presented. The lack of findings may be a result of the fact that the included studies in this review assessed the recovery after exercise using different blood markers. Therefore, there is a risk that some of the blood markers is only assessed by one study. As in this review, Romero-Parra et al. (14) is the only resistance exercise study including the previously mentioned blood markers.

4.3 Comparison between the results from the endurance exercise and resistance exercise.

When comparing the results on how recovery is affected by MCP in endurance and resistance exercise, there is some interesting findings regarding CK activity and IL-6. CK activity and IL-6 is the only blood marker that is assessed for both exercise methods in the included studies and is therefore the only blood marker that can be directly compared between endurance and resistance exercise. Whereas there was found no significant effect of MCP on CK activity after resistance exercise, there was observed a significant rise in CK values in MFP rather than MLP after endurance exercise. Callegari et al. (26) researched the differences in CK levels between endurance and resistance exercise. Their results showed that the CK values got significantly more elevated after the endurance exercise with VO2max at 80%, compared to the values after resistance exercise. This study researched men, but it is reasonable to assume that the difference in CK between the exercise methods is relevant for females too. These results may explain the reason why the CK values in the MCP comparison is not significant for resistance exercise, and one therefor does not see an effect of MCP on recovery after resistance exercise. It is reasonable to assume that the greater the CK-value is, the more pronounced is the differences among the MCP.

Another thing to take into consideration is the difference in exercise duration between the endurance and the resistance studies. The endurance studies had the participants complete a running session with a duration from 60-90 minutes on three of them, and one study that had the participants run to exhaustion. Compared with the studies on resistance exercise, their exercise duration was a bit shorter. These studies did not use time as a measurement, but the longest exercise would probably be the one with drop jumps (12), where the participants completed 100 jumps with a 20-sek interval. A longer exercise duration could lead to a greater muscle tissue damage, that would elevate the CK values in the blood. Because of this, the duration of an exercise session is relevant as an impact on the CK values.

4.4 Study design and sample size

The included studies for both endurance and resistance had different study designs. The subjects included in the endurance studies (8–11) had to perform running sessions with different durations and intensity. In the resistance studies some of the subjects performed exercise involving the lower libs (12,14), some in the elbow (13) and some performed a downhill running session (15). This will have a negative effect on the ability to compare the studies included for endurance or resistance. When the duration, intensity and exercise is varying between the studies, it can affect the values on the different blood markers. In this review, this affects the studies included for the resistance exercise the most, since they have the most varying exercise methods. It would therefore be difficult to make a sure statement that these studies provide all the right answers on the effect of MC on recovery after exercise. Another factor that is worth to consider is that some of the blood markers included in the review are only assessed once e.g., testosterone and leukocyte. This makes the results on these blood markers uncertain, when one can only provide results from one study. If there had been more studies including the different blood markers, the results observed regarding the effect of MC on exercise recovery would be more valid. One last factor that influence the founding’s in this review, is the sample size on the included studies. The largest sample size in the included studies had a number of 24 participants (13), where the rest of the studies had under 20 participants (8–12,14,15). With small sample sizes ass these one could risk that eventual individual factors, that have an influence on the results, could have an impact on the group results. This would make the observations from the studies less valid, then if the sample size had been bigger.

5 Conclusion

Based on the information that has been conducted in this review, the MC is found to influence the recovery after endurance exercise. For both CK, IL-6 and blood lactate the values indicate a longer and more needed recovery period in the MFP. The testosterone values indicated no effect by the MCP on the recovery. Results on recovery after resistance exercise indicates no special effect of the MC on this type of recovery, for none of the blood markers. One can therefore conclude with that the MC shows to have a greater impact on recovery after endurance exercise compared with resistance exercise. Nevertheless, this is still a highly relevant subject that is necessary to assess more extensive.

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