Athletic Performance and the Oral Contraceptive

Claire Rechichi, Brian Dawson, and Carmel Goodman

Some reports suggest variation in physiological responses and athletic performance, for female athletes at specific phases of the menstrual cycle. However, inconsistent findings are common due to the inappropriate verification of menstrual cycle phase, small subject numbers, high intra- and interindividual variability in estrogen and progesterone concentration, and the pulsatile secretion of these hormones. Therefore, the oral contraceptive (OC) cycle may provide a more stable environment in which to evaluate the acute effect of reproductive hormones on physiological variables and exercise performance. To date, most of the OC research has compared differences between OC use and nonuse, and few researchers have examined within-cycle effects of the OC. It is also apparent that OC use is becoming far more prevalent in athletes; hence the effect of the different exogenous and endogenous hormonal profiles on athletic performance should be investigated. Research to date identifies potential for variation in aerobic performance, anaerobic capacity, anaerobic power and reactive strength throughout an OC cycle. The purpose of this review is to present and evaluate the current literature on the physiology of exercise and athletic performance during the OC cycle.

Keywords: female, athletes, hormones, menstrual cycle

Background

The modern combination oral contraceptive (OC) comes in a variety of types and formulations that contain various concentrations of synthetic estrogen and progestogen. These agents typically contain one type of synthetic estrogen, ethinyl estradiol (EE) and the progestogen component can be present in up to eight different forms. The different progestogen derivatives have unique biological properties, which relate to their respective potencies and relative binding affinity (RBA).¹ The potency of progestogen largely depends on its ability to bind to the progestogen receptor, while its androgenicity is determined by the capacity to bind to androgenic receptors. High potency progestogens have a greater RBA to the progestogen

---

151
receptor and therefore exert the progestational effects necessary for contraception with a smaller dose. Progestogens that have a high androgenic RBA are known to produce undesirable side effects that counteract the positive effects of estrogen. The variation in exogenous steroid profiles between the OC preparations should be considered when evaluating the effects of contraceptives, given that the potency, androgenicity and ratio of hormones may influence the impact of OC cycle phase on athletic performance.

It is apparent that OC use is becoming more prevalent in athletes. Prior et al in the early 1980s reported only 5 to 12% of athletic women were using an OC. In the late 1990s Brynhildsen et al reported that 47% of female team sport athletes used an OC agent. Unpublished survey results (Rechichi, 2000), found that in 89 athletes from 11 different sports (mean age 24 years, ranging from state to international level), 55% were taking an OC and of these athletes 78% took a monophasic preparation and 22% a triphasic preparation. More recently, an unpublished survey of 68 athletes from 15 different sports (Rechichi, 2008) reported increased OC use, with 83% of elite level athletes (mean age 25 years) taking an OC (98% monophasic and 2% triphasic).

Despite the widespread use of OC agents among athletes, few researchers have examined the effect of acute hormonal fluctuation within an OC cycle on the exercise responses of women. Most of the literature has focused on assessing the physiological differences between OC users and nonusers, or responses before and then during OC use. The lack of within-OC cycle research compounds the largely inconclusive findings of the existing literature on OC use and athletic performance. It is unclear whether differences resulting from OC intervention are a result of the intervention itself or the biological variation existing within an OC cycle. The purpose of this review is to present and evaluate the research on variations in physiology and performance associated with the acute hormonal fluctuation within an OC cycle. The authors acknowledge the existence of other types of OC agents (eg, depo provera, progestogen only and biphasic combinations), but given limited use of these formulations by athletes, this review will focus on monophasic and triphasic preparations.

**Hormonal Profiles of Oral Contraceptive Users**

Oral contraceptive use generally involves a dose of estrogen and progestogen over 21 d (OC consumption phase), followed by 7 d of placebo (OC withdrawal phase). The dosage of EE in the monophasic pill is constant and averages 0.03 mg/d (different brands range from 0.02 to 0.05 mg/d), while in the triphasic preparations, the dosage may vary or remain constant, usually between 0.03 and 0.04 mg/d. For both monophasic and triphasic preparations the type of progestogen, dosage, potency and androgenicity can vary between brands. A summary of the steroid hormone concentrations of commonly used OC brands, was detailed by Burrows et al. The primary role of the combined pill is the suppression of the hypothalamic-pituitary system (including the endogenous production of estrogen and progesterone), which prevents the midcycle surge of gonadotrophins, inhibiting ovulation and subsequent pregnancy. Serum levels of EE peak approximately 1 h after ingestion, fall rapidly for the following 6 h and then decline slowly. Approximately 24 h after ingestion, 33% of EE remains in circulation compared with
about 20 to 25% of progestogens. However, EE is detectable for up to 2 d after discontinuation, while some progestogens are detectable for up to 5 d. Therefore, early in the withdrawal phase both endogenous estrogen and progesterone continue to be suppressed, but later in the withdrawal phase endogenous estrogen levels may rise while progesterone levels stay suppressed. Given the different half lives of the exogenous steroids and variable impact on the endogenous hormones, researchers should consider the withdrawal phase as a transient hormonal profile. Typical exogenous steroid doses and endogenous hormone profiles over the course of a single OC cycle are presented in Figure 1.

### Oral Contraceptive Use and Exercise Performance

#### Aerobic Exercise

A significant reduction (5% to 15%) in peak oxygen uptake (VO₂) is associated with OC use in active or trained women. Monophasic OC use has also been associated with an increased oxygen consumption for standardized workloads. In these studies physiological and performance capacities were assessed before and during OC treatment. Within OC cycle variation in ventilatory measures, VO₂ and substrate metabolism has the potential to affect aerobic performance.

#### Ventilatory Measures

Elevated progesterone levels can increase respiratory drive via a centrally modulated response that includes increased chemo sensitivity to hypoxia and hypercapnia. Two studies have reported increased ventilation (Vₑ) and/or Vₑ/VO₂, during the OC consumption phase when progestogen levels are highest. Rechichi et al. assessed 13 well-trained cyclists, who performed a 1-h cycle endurance test three times throughout a monophasic OC cycle, once during OC consumption and twice in the withdrawal phase. Despite no difference in performance, mean Vₑ (~7%) and Vₑ/VO₂ (~5%) were significantly higher during OC consumption, compared with both withdrawal phases. It is unclear whether exercise of greater duration would elicit greater fatigue and diminished performance. Reilly et al. also reported an increased Vₑ/VO₂ (~8%) during the OC consumption phase (compared with the withdrawal phase), for trained runners performing a treadmill test to exhaustion at 70% VO₂max (~55 min). However, the raised Vₑ/VO₂ was only present after 30 min of exercise and the authors did not report a difference in Vₑ, or time to exhaustion between the two OC phases. Some caution should be exercised when interpreting these results as the study sample was small (n = 4).

It is possible that the ventilatory variation between the OC phases is dependent upon exercise duration and intensity, given that Giacomoni et al. found no substantial difference in ventilation measures throughout a monophasic OC cycle. Their research was conducted on 10 untrained participants, performing three sets of 4-min submaximal exercise bouts on a treadmill during the OC consumption and OC withdrawal phase. Variation in ventilatory findings across the three studies may also relate to the different types of monophasic OC agents used. OC agents containing the third generation progestogens (desogestrel and gestodene) might not have the same effect on ventilatory function as natural progesterone or...
**Figure 1** — Cyclical variation of endogenous and exogenous hormones throughout a 28-day oral contraceptive cycle for general (a) monophasic and (b) triphasic preparations. Oral contraceptive withdrawal phases are indicated.
the earlier progestogen formulations. Another explanation is that the fitness level of the participants could account for the difference in the findings. Two further studies conducted on untrained subjects did not observe substantial differences in ventilatory measures throughout an OC cycle. However, the relevance of these findings is somewhat limited because performance was tested when the synthetic hormone intake was similar (OC consumption phase), as opposed to making a comparison between the OC consumption and OC withdrawal phases, when there is a greater contrast in hormone levels. Further research is necessary to clarify whether the various types of OC agents, generate different ventilatory responses throughout an OC cycle and whether training status is also an influence.

**Oxygen Consumption**

The only research to have demonstrated variation in exercising oxygen consumption (VO$_2$) throughout an OC cycle, was conducted by Giacomoni et al. on 10 untrained participants using a monophasic OC. Submaximal VO$_2$ was 3.0% to 5.8% lower in the OC consumption phase compared with the OC withdrawal phase, across three submaximal treadmill exercise bouts. There was no evidence of substantial heart rate, ventilatory or substrate differences throughout the OC cycle, so the authors attributed the improved running economy during the OC consumption phase to biomechanical factors. Although estrogen can affect the composition and architecture of many human tissues including muscle fibers, ligaments and tendons as well as neuromuscular control and force transmission pathways, there is no evidence to support the assertion that an acute increase in sex steroids improves running mechanics.

In contrast to the findings of Giacomoni et al., research conducted on untrained and trained monophasic users, untrained triphasic users, and both monophasic and triphasic OC users did not demonstrate any substantial difference in VO$_2$ throughout the OC cycle. However, the findings of some studies are limited because testing was conducted at two times when progestogen intake was similar (during OC consumption). Overall the findings are unclear and further research is necessary to determine whether variation in VO$_2$ and running economy exists throughout an OC cycle and the mechanisms involved. Research is also required to determine the effects of triphasic preparations on physiological response and performance.

**Substrate Metabolism**

Endogenous sex hormones may have secondary effects on substrate metabolism. Estrogen has been linked to increased lipid and reduced carbohydrate oxidation during exercise, primarily due to altered secretion rates of lipolytic and glucoregulatory hormones such as growth hormone (GH), insulin and glucagon. Progesterone is reported to oppose the lipolytic effects of estrogen. The synthetic hormones found in OC agents also appear to alter fat and carbohydrate metabolism, glucose flux and insulin sensitivity.

Research on metabolism and performance throughout an OC cycle is sparse. During the OC consumption phase when estrogen levels are high, it is possible that the potential glycogen sparing effect would enhance sustained athletic perfor-
mance. In contrast, Rechichi et al.\textsuperscript{8} found no significant variation in 1-h cycling performance in trained athletes taking a monophasic OC: blood lactate values were higher during OC consumption than the withdrawal phases. In support, Redman et al.\textsuperscript{31} also found higher postexercise lactate concentrations during OC consumption, for five triphasic OC users completing an anaerobic capacity test. Lynch et al.\textsuperscript{30} also studied five untrained women completing an intermittent exercise protocol to exhaustion: peak blood lactate concentration was higher during the first week compared with the second week of OC use. Unfortunately there was no assessment in the withdrawal phase and given the subjects were taking a monophasic OC, the expected hormonal milieu would have been very similar between tests. The variation in results was more likely the result of an order effect. Further research\textsuperscript{24} reported no variation in blood lactate between OC consumption and withdrawal. Overall the existing data pertaining to OC use and aerobic exercise reject the hypothesis generated by previous menstrual cycle and substrate metabolism research; and does not support glycogen sparing during the OC consumption phase, nor does it suggest any direct link within an OC cycle between acute hormone variation and blood lactate concentration.

High levels of estrogen have been linked to increased serum GH levels and large doses of progestogen to decreased serum GH levels.\textsuperscript{32} However, some authors have found no significant difference in GH response to exercise throughout an OC cycle,\textsuperscript{29,32} suggesting that the OC hormones counterbalance each other to maintain homeostasis of GH levels. Bonen et al.\textsuperscript{27} demonstrated an increased GH concentration during OC consumption in seven monophasic OC users, but the GH response had little metabolic significance. There was no concomitant increase in glucose, lactate, glycerol, cortisol, glucose or free fatty acid (FFA) concentration in this study. In addition, the GH difference was only apparent during lower intensity exercise (40\% vs. 85\% \textit{VO}_{2\text{max}}). Bernades et al.\textsuperscript{24} supported the impact of exogenous OC steroids on GH, following the assessment of seven women taking either a triphasic or monophasic OC combination. For both continuous (60\% \textit{VO}_{2\text{max}}) and intermittent exercise (>80\% \textit{VO}_{2\text{max}}) GH response was greater (94\% and 250\% respectively) during OC consumption versus OC withdrawal. The authors proposed that exercise performance could be enhanced during OC consumption when GH levels are elevated. However, a clear link between GH and performance is yet to be established and no research to date has assessed performance in conjunction with GH levels, throughout the OC cycle. Based on current findings, variations in GH levels during an OC cycle do not appear to exert significant effects on substrate metabolism during higher intensity exercise.

**Conclusions and Recommendations**

There is little evidence to suggest that acute hormonal fluctuation throughout an OC cycle significantly affects aerobic performance. Differences in ventilation, oxygen consumption and substrate metabolism between studies appear to relate to variations in the types of OC used and the dosage of progestogen administered. The majority of within-cycle aerobic exercise research has been conducted on monophasic OC use, and studies on triphasic formulations are needed to complement these data. Additional observational and randomized controlled trials on
relationships between OC use and exercise responses are required before definitive clinical guidelines for athletes and coaches can be developed.

**Anaerobic Exercise**

Research into anaerobic performance throughout either a menstrual or an OC cycle is scarce. Potential mechanisms underpinning variation in anaerobic performance throughout an OC cycle include the effects of ethinyl estradiol (EE) and progestogen on substrate metabolism, buffering capacity, strength and neuromuscular function.

**Anaerobic Capacity**

There is growing recognition that estrogen and progesterone have important roles in regulating substrate metabolism during exercise. Estrogen acts to increase lipid and reduce carbohydrate oxidation during exercise. These effects imply that anaerobic capacity would be enhanced during OC withdrawal when circulating levels of the sex hormones are lowest and carbohydrate metabolism is up regulated. Falls in progesterone levels have been linked with increased aldosterone activity (as progesterone is an antagonist at the aldosterone receptor site). When progesterone is lowered during OC withdrawal, the increased circulating aldosterone could potentially increase fluid and electrolyte retention, buffering and anaerobic capacity.

Anaerobic capacity can be defined as the maximal amount of ATP resynthesized via anaerobic metabolism during a specific bout of short-duration exercise. To our knowledge only Redman et al has reported a significant difference in anaerobic capacity during an OC cycle. Performance during a 1000-m rowing time trial was significantly better during withdrawal compared with OC consumption (226.5 ± 1.3 s vs. 230.6 ± 1.4 s), when exogenous EE and progestogen levels were lowest. This finding was associated with increased glucose and reduced plasma triglyceride concentrations during exercise. The difference in anaerobic capacity was attributed to the secondary cellular effects of EE and progestogen on substrate utilization and buffering capacity. In contrast, De Bruyn-Prevost et al. did not find any significant difference in performance time throughout an OC cycle, for seven untrained subjects who maintained a fixed intensity cycling load for as long as possible. The training status of the subjects, protocol type, mode of exercise, possibly the OC type used (not specified) and the protocol length (approximately 228 s vs. 31 s) differed between these two studies. It is possible that the duration of activity is a significant factor in determining whether the OC cycle phase has a substantial effect on anaerobic performance. With a shorter test, there is less reliance on glycogen and lipid utilization and possibly less opportunity for exogenous steroids to exert their influence. In addition, the results of the latter study should be interpreted with caution because the test was performed immediately after an aerobic test to exhaustion. For a valid assessment of anaerobic capacity, it is important that the participant’s present in a rested state. Further research is warranted to clarify whether anaerobic capacity is altered substantially during the OC cycle and the mechanisms involved. If the fluctuation in aldosterone influences buffering capacity and subsequent anaerobic performance, future
research should make assessments in the OC consumption phase and twice during OC withdrawal, given the progesterone/aldosterone ratio varies throughout the withdrawal phase.³³

**Anaerobic Power**

Only one study has demonstrated substantial variation in anaerobic power throughout an OC cycle.³¹ Redman et al³¹ found that for five trained triphasic OC users, anaerobic power (assessed during a 10-s all-out row), was greatest during the withdrawal phase compared with the OC consumption phase. No mechanism for the difference in anaerobic power was proposed. At present there is no evidence to suggest that muscle phosphate stores or utilization are affected by estrogen or progesterone levels. This claim is supported by three independent studies on 10 monophasic users³⁵,³⁶ and 17 users (taking a combination of monophasic and triphasic preparations),³⁷ who found no significant difference in anaerobic power throughout an OC cycle, based on tests of cycling power, jumping power, and stair climbing performance.

Despite no difference in anaerobic power, Rechichi et al³⁵ reported substantial variation in reactive strength throughout an OC cycle in trained athletes. Previous research has indicated that reactive strength and the stretch-shortening cycle are determinants of sprinting and jumping performance.³⁸ A drop jump was used to assess reactive strength and performance was significantly worse, late in the OC withdrawal phase (compared with the OC consumption phase) when exogenous EE and progestogen have cleared, but endogenous estrogen levels have started to rise. Estrogen receptors are present in skeletal muscle, which may provide a plausible tissue-based mechanism for influencing neuromuscular control and force transmission pathways.¹⁹ Rechichi et al³⁵ suggested that endogenous estrogen may have had a negative impact on neuromuscular timing and muscle activation time, which in turn affected performance late in the withdrawal phase. Given that performance was best during OC consumption when exogenous estrogen is highest, EE contained in OC agents might not influence muscle receptors in the same way as endogenous estrogen. An alternative proposition was that the increased level of progestogen during OC consumption, affects the interaction of estrogen and the neuromuscular pathway. Further research is warranted to determine how the reproductive hormones influence the stretch shortening cycle and whether the ratio of these hormones (endogenous and/or exogenous) influences the impact of the OC cycle phase on neuromuscular athletic performance. Variation in findings within the withdrawal phase, reinforce the need for future research to consider the withdrawal phase in two distinct parts.

**Strength**

Fluctuations in isometric strength throughout a regular menstrual cycle have been attributed to estrogen exerting a positive effect on skeletal muscle function, and progesterone inhibiting the effects of estrogen.³⁹ Petrofsky et al⁴⁰ reported that muscle temperature varied throughout a menstrual cycle and suggested that higher levels of progesterone were associated with an increased core muscle temperature. This outcome may result in a limiting temperature being reached earlier
during exercise, therefore reducing muscular endurance. These researchers neglected to measure hormone concentrations, making it difficult to confirm a relationship between hormone levels and strength.

The data pertaining to the effect of OC use on muscular strength and performance is minimal and inconclusive. Currently we are aware of only five studies that have examined muscular strength throughout an OC cycle. Two studies demonstrated no substantial difference in maximal handgrip strength or endurance throughout an OC cycle. Unfortunately, Petrofsky et al. only used three subjects who were taking an older monophasic OC formulation and Wirth et al. did not appropriately define testing times to enable within OC cycle analysis. It appears that the subjects were tested twice during the OC consumption phase, making the results difficult to interpret. Other research that compared OC consumption and withdrawal phases also failed to demonstrate any difference in maximal force generating capacity within a monophasic OC cycle. The research by Elliot et al. was a well controlled study on 14 monophasic OC users that showed neither maximal dynamic and isometric leg strength, nor isometric strength of the first dorsal interosseus muscle, varied between OC phases. In agreement, Sarwar et al. showed no within OC cycle variation for handgrip strength and also isometric quadriceps strength in monophasic users. Finally, Peters et al. who has conducted the only study on trained athletes, assessed maximal leg isokinetic extension and flexion in 12 monophasic OC users and demonstrated no difference in maximal strength throughout the OC cycle.

More research is necessary to clearly determine the effects of OC cycle phase on anaerobic performance. To date, research has indicated potential for variation in anaerobic capacity and reactive strength. Despite previous speculation that the sex hormones may affect muscular strength, it appears that the modern OC formulations do not provide enough androgenic influence to substantially alter muscular strength and anaerobic power throughout an OC cycle. Future research should focus on the mechanisms affecting anaerobic capacity and reactive strength during the OC cycle.

**Repeated High Intensity or Intermittent Performance Measures**

Most team sports require participants to repeatedly produce high intensity efforts (with variable recovery intervals) throughout a game, making it important for team sport players to develop repeated sprint ability. To date we are only aware of three studies that have examined this type of performance throughout an OC cycle. Rechichi et al. found no significant difference between OC phases for total work completed, work or power decrement during a 5 × 6 s repeated sprint ability cycle ergometer test. Two other studies led by Lynch showed no difference in performance time on a final run to exhaustion, following five intermittent high-intensity 20-s runs at two time points of an OC cycle. Unfortunately, both tests were conducted at times when the exogenous hormone intake was similar (during OC consumption), making it difficult to draw any conclusion on within OC cycle effects on intermittent performance. In summary, two of the three studies are inconclusive, while the other suggests that repeated sprint activity is not affected...
by the phase of the OC cycle. However, this finding is based on only monophasic OC use and further research is necessary to support these findings.

Conclusions and Recommendations for Future Research

The purpose of this review was to evaluate research pertaining to variation in athletic performance, associated with acute hormonal fluctuations experienced throughout an OC cycle. The examination of physiology and performance within an OC cycle is novel to this review and indicate potential for variation in: (i) aerobic performance, based on altered ventilatory responses; (ii) anaerobic capacity, based on substrate metabolism and buffering capacity mechanisms; (iii) anaerobic power; and (iv) reactive strength, throughout an OC cycle. However, the results of the small number of research studies to date are conflicting. Investigators disagree on the effects and mechanisms involved in physiology and performance at different phases of the OC cycle. The variation in experimental findings between studies is most likely the result of: (i) the use of different types of OC agents (monophasic vs. triphasic); (ii) different OC formulations (particularly varied concentration, androgenicity, and potency of the progestogen component); (iii) varied definitions of the OC phases; (iv) small sample sizes; (v) variation in the training status of the subjects; and (vi) the different exercise protocols employed. Future research needs to address these issues and examine the effects of extended OC consumption; including the use of monophasic OCs by athletes to manipulate their cycle to avoid menstruation.

References


