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Effects of oral contraceptive use on the salivary testosterone and cortisol responses to training sessions and competitions in elite women athletes

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HIGHLIGHTS

- OC use can lower the T levels of women across training and competition activities
- T and C reactivity was reduced in OC women when the activity data were combined
- Heavy training, club and International competitions all increased T and C levels
- Theoretical hormone-behavior models should consider OC use and the activity demands

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ABSTRACT

This study examined the salivary testosterone (T) and cortisol (C) responses of elite women hockey players across 4 activities (light and heavy training, club and International competitions). The players formed an oral contraceptive (OC) group ($n = 10$) and a Non-OC ($n = 19$) group for analysis. The Non-OC group had higher T levels (by 31–52%) across all activities, whilst the OC group showed signs of reduced T and C reactivity when data were pooled. As a squad, positive T and C changes occurred with heavy training (45%, 46%), club competitions (62%, 80%) and International competitions (40%, 27%), respectively. Our results confirm that OC use lowers T levels in women athletes whilst reducing the T and C responses to training and competition activities within the sporting environment. Differences in the physical and/or psychological demands of the sporting activity could be contributing factors to the observed hormone responses. These factors require consideration when applying theoretical models in sport, with broader implications for women around exercising behaviours and stress physiology.

1. Introduction

In the past decade, there has been growing interest in the role of testosterone (T) and cortisol (C) in women's athletic competition [14,16,17,22,25,36]. This research is often based on theoretical models relating to the gaining, maintaining and losing of social status, which has both dominance and stress components [33,44]. According to the biosocial status hypothesis [33], a bidirectional relationship exists between T and dominance such that T levels increase to encourage behaviour aimed at dominating others, and an experience of dominance might itself increase T secretion to reinforce these behaviours. Cortisol provides an indexed marker of stress activation (of the hypothalamic–pituitary–adrenal [HPA] axis) in preparing for, and responding to, sports training and competition [28].

Research on women in competition is consistent with these theoretical models. Women's salivary T and C levels often rise before a competition [2,14,36] with these changes linked to playing abilities [17], bonding, aggressiveness and focus [2]. Sports competition (e.g. rugby, tennis, soccer, volleyball, wrestling) can promote further hormonal increases [2,14,16,17,22]. The percent changes in C are generally much larger than T and possibly due to physical exertion, the psychological stress of competition, or some combination of the two. Winning in sport has also been associated with an elevated T response (vs. losing) [25,36], subsequently leading to positive changes in athlete mood state and anxiety levels [36].

There are instances when T has not responded to sports competition in women [19,28–30]. This may be explained by the shorter duration and individual nature of some competitions (e.g. 2 km rowing trial,

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power lifting). In addition, simulated events are often examined and these are likely to be less threatening to social status and less stressful than actual competition [12,37]. Still, practice matches in sport can promote hormonal changes comparable to real events [14], perhaps arising from greater physical exertion and psychological aspects around this (e.g. mental effort, motivational drive). To better understand the stressors of elite sport and the resultant hormonal change, it would be informative to compare the T and C responses to training sessions that differ in physical intensity and to competitions of varying social importance. To our knowledge, no research of this nature has been conducted on elite women athletes.

Oral contraceptive (OC) use may impact women's baseline T and perhaps, her T response to training and/or competition. Many reports indicate that OC usage can decrease the blood or salivary levels of T and other androgens (e.g. dehydroepiandrosterone, dehydrotestosterone, androstenedione) in healthy women [9,21,42,43,45]. In fact, postmenopausal women with prior OC use had a lower T profile than non-users, suggesting long-term changes in hormone status [8]. On average, the OC-related decreases in free T levels are much greater (61%) than that observed for total T (31%) and likely due to OC-related increases in steroid binding proteins (e.g. sex-hormone-binding globulin) [9,45], thereby reducing the bioactive free steroid, along with the suppression of ovarian and adrenal androgen synthesis [45].

In studies of women athletes, OC users commonly exhibit lower blood or salivary T levels than nonusers (Non-OC) [3,15]. Still, OC women are responsive to sports competition with comparable T increases (percent and delta change) to Non-OC women [14,15]. Others have identified similar T changes to prolonged exercise in untrained (OC, Non-OC) and trained (OC) women [18], although the latter group had lower circulating T before and after exercise. Whilst the female T response appears relatively stable across different concentration ranges, some evidence suggests that OC usage can inhibit the free C responses to physical [4,27] and psychological stress [5,26]. These effects have yet to be validated in an ecologically valid setting when women are exposed to a mixture of physical and/or psychological stress (e.g. sports training and competition).

This study examined the salivary T and C responses of elite women hockey players across different sporting activities (i.e. light and heavy training sessions, club and International competitions) in a naturalistic setting and possible interactions with OC use. Based on prior research we formulated the following hypotheses: first, the OC group would exhibit lower T (but similar C) levels than the Non-OC group across all activities; second, the OC group would also show a smaller C (but similar T) response across these activities; third, overall the T and C responses would vary by activity type, being higher in International than club competitions, followed by heavy training and then light training sessions.

2. Materials and methods

2.1. Participants

Twenty-nine elite women hockey players were recruited, with a mean age of 25.3 ± 2.1 years, height of 176.9 ± 9.4 cm, body mass of 71.7 ± 19.8 kg and body mass index of 22.4 ± 1.3 kg/m^2. The players were part of an International training squad at the start of the 2011 regular season. A field hockey team is made up of 11 players and 5–7 substitutes covering 4 generic positions: goalkeepers, defenders, midfielders and attackers. All of these positions were represented within the study cohort. As part of the consent procedures, the athletes were asked about current hormone contraceptive use (e.g. oral pill, injection, implantable, or patch-delivered) [14,15]. Only OCs were reported ($n = 10$), with the remaining players classified as Non-OC users ($n = 19$) for the purpose of this study. The Non-OC group reported having regular menstrual cycles, between 26 and 32 days without self-noticed problems. This study was performed with ethical approval from the Swansea University Research Ethics Committee, Swansea, UK, and participants provided written informed consent.

2.2. Experimental procedures

A 2-group, quasi-experimental design with repeated measures was used to address the study hypotheses. The OC and Non-OC groups were monitored over an intensive 15-day training block in which 13 training sessions were completed (with data taken from 7 training sessions) with 3 club and 4 International competitions played. Table 1 outlines the type and timing of each activity. Saliva samples were collected before and after selected training sessions (i.e. light $n = 4$, heavy $n = 3$) and all club and International competitions to monitor T and C levels and changes from baseline. The experimental procedures were performed under normal sporting conditions to improve the ecological validity of the study findings.

2.3. Training and competition schedule

The training sessions were performed at a National centre for elite sport. These sessions lasted approximately 2 h and involved a combination of skill (e.g. hockey team training) and/or physical (e.g. weight training, cardiovascular) conditioning. The weight training and cardiovascular sessions were generically classified as gym training sessions. In total, 50% of athlete training focused on skill/team development and the remaining 50% on physical conditioning. All training activities were pre-planned to optimize the training load and thus, athlete performance and recovery, relative to the competition schedule. The prescription of "light" and "heavy" sessions was part of this process, and confirmed by subjective ratings of perceived exertion (RPE) on a 1–10 scale, with a lower RPE ($p < 0.001$) after light training (4.7 ± 0.4) than heavy training (7.1 ± 0.2). This is a standard approach in sport to ensure that the training loads for each athlete can be easily quantified and managed [20]. A 10-minute warm-up was performed before any training session.

The club and International competitions each lasted 80 min played in 2 periods of 35 min with a 10-minute interval. A more intensive warm-up was performed before each competitive game, lasting around 45 min. The club competitions were played at various locations, as part of a National premier hockey league tournament involving 10 teams, with the recruited athletes distributed amongst these teams. The RPE scores from the club (6.9 ± 0.3) and International competitions (7.3 ± 0.2) were similar to each other ($p = 0.344$), and heavy training ($p > 0.521$), but superior to light training ($p < 0.001$). The International competitions were played against 2 different opponents (2 games each) at the home venue of the current squad, thereby eliminating the possible influence of playing venue (i.e. home vs. away) on the hormonal outcomes, as seen in men [7,34].

The International team in this work had a higher European field hockey ranking (number 3 in European ranking) than their opponents (numbers 5 and 8) at the time of this study. This is reflected in the game outcomes, with the International competitions won by the current team (in order) with scores of 2–1, 2–0, 4–0 and 6–0. The number of athletes completing each activity varied according to prior exercise programming, game selections and the timing of competition, as well as any unforeseen injuries and illnesses. Most participants completed the heavy training sessions ($n = 26–28$), but the numbers varied during

Table 1
Training and competition schedule over the 15-day monitoring period.

DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
AM 9–12	R	GT	LT	GT	R	R	LT	IC LT	GT	LT	GT	R	R	LT	LT
PM 2–5	HT	R	HT	R	CC	CC	IC	R	R	HT	R	R	CC	IC	IC

Notes: R = rest, GT = gym training, LT = light training, HT = heavy training, CC = club competition, IC = International competition. The shaded cells indicate those activities with hormone data taken.