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Testing men's hormone responses to playing League of Legends: No changes in testosterone, cortisol, DHEA or androstenedione but decreases in aldosterone

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ABSTRACT

Esports, or competitive video gaming, has rapidly increased in online play and viewing. The popularity of esports such as League of Legends may derive in part because it features skills-based coalitional competition. Whereas a sizable literature focuses on adult human hormones and competition, little research has addressed the hormone responses of men playing video games. The purpose of the present study is to investigate the effects of playing a coalitionary-based esport on young U.S. men's steroid hormone levels in a naturalistic study. We tested salivary steroid changes in response to esports club members ($n = 26$) playing League of Legends against other people and the computer. We hypothesized that esports competition would increase testosterone, cortisol, DHEA and androstenedione levels, with more pronounced increases in winners than losers. Participants provided saliva samples before and after competitions lasting 15–27 min in duration. Salivary testosterone, cortisol, DHEA and androstenedione levels did not change overall or between play against people vs. the computer or with respect to winning or losing. However, play duration (range 16–27 min) was positively related to changes in DHEA, androstenedione and testosterone during play against people. Aldosterone levels decreased overall. We suggest that the informal and familiar environment as well as relatively short play duration help account for generally null findings. These findings help document physiological effects of esport play, in turn contributing to a richer understanding of why so many play and watch esports.

1. Introduction

Electronic sports (esports) is expanding rapidly in the U.S. and many parts of the world (Li, 2016; Seo & Jung, 2016; Taylor, 2012). A variety of social and technical factors contribute to this recent rise in esports popularity. Improvements in Internet speed and computer graphics offer more technically compelling forms of competition, with platforms such as Twitch helping ratchet up the scale of play quality and fandom (Li, 2016). Among young adults characterized by delays in adult milestones like establishing an independent household or having children, a community of predominantly young men can find opportunities for competing, often socially, in esports (Twenge, 2017). The ability to play or watch online with others enables social and competitive experiences even if busy school or work schedules and living circumstances limit face-to-face encounters (Hamari, Hamari, Sjöblom, & Sjöblom, 2017; Lee & Schoenstedt, 2011). A growing number of dedicated esports facilities also foster in-person play and watching experiences.

In 2014, there were some 67 million League of Legends players monthly, and annual revenue was around $1 billion, making it the most popular esport globally (Li, 2016). League of Legends involves teams of 5 players competing against each other to destroy the enemy's "nexus," or base structure. Players select a character (Champion) possessing heroic and symbolic talents. Players coordinate with teammates, with the gaming environment demanding skill and strategy. Reasons for the success of League of Legends may include a low barrier to entry (free play, with purchase of additions like weapons during play possible) and the social aspects of competitive team play. There may be parallels between the success of League of Legends and popular athletic sports in featuring coalitional, skill-based competition (Apostolou, 2015).

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The purpose of the present research is to investigate the effects of playing League of Legends on young U.S. men's steroid hormone levels. A naturalistic study design was employed to test effects on men accustomed to playing League of Legends in a regular venue and community. This research helps contribute to work on the physiological effects of esport play, which itself may be of value in understanding how and why so many play esports recreationally. This research also connects with a body of hormones and human behavior research on the stress response and social competition, taking those concepts and empirical work into this newer niche of esports, potentially thus enriching both areas of study through this relatively novel bridge. If young men playing League of Legends exhibit similar hormone changes observed in other domains of social competition, this may help shed empirical light on the visceral responsiveness and perhaps appeal of esports.

How do steroid hormones reflect and organize human behavior? (Ellison & Gray, 2009; Nelson & Kriegsfeld, 2016)? Hormones such as testosterone and cortisol are pleiotropic, meaning they have multiple effects. Yet these multiple effects often serve functional ends. In response to a stressor such as a stimulus warranting a fight-or-flight response, hormones such as cortisol and aldosterone might increase to prepare the body to rapidly mobilize energy, cognitively focus, and shunt attention away from other less-immediately important functions such as reproduction or digestion (McEwen et al., 2015; Sapolsky, 2017). Moreover, a suite of androgenic hormones such as androstenedione and testosterone may both increase the likelihood of engaging in socially competitive encounters as well as reflect the consequences of such encounters, possibly biasing future behavioral responses to competition (Geniole, Bird, Ruddick, & Carré, 2017; Nelson & Kriegsfeld, 2016; Soma, Rendon, Boonstra, Albers, & Demas, 2015). Androgenic hormones may exert their effects through binding of the androgen receptor, with both rapid-action (i.e., cell surface interactions) and longer-standing effects (i.e., gene regulation) possible. DHEA is an abundant androgenic hormone primarily released by the adrenal gland in young men that may have some direct effects through interactions with other hormones (e.g., antagonistic interactions with cortisol) or neurotransmitters; DHEA can also be converted to the androgenic hormone androstenedione, which itself can be converted to testosterone (Soma et al., 2015). Thus, steroid hormone pathways may permit DHEA and androstenedione to exert primary effects after conversion to testosterone, the primary androgen involved in adult men's behavioral responses.

A large literature addresses hormone responses to men competing. Most of this literature has focused on two hormones—testosterone and cortisol. Drawing upon the “Challenge Hypothesis” for inspiration (Wingfield, Hegner, Dufty, & Ball, 1990), studies have tested patterns in men's testosterone responses to both athletic (e.g., individual and team sports) and non-athletic (e.g., playing poker) competition. In a meta-analysis, Geniole et al. (2017) showed that competition regularly induces acute changes in men's testosterone, and that relatively greater changes in winners than losers more often appear in non-lab settings. For example, winners of chess competitions had relatively higher testosterone changes than losers, with effects more pronounced in close rather than easy matches (Mazur, Booth, & Dabbs, 1992). Moreover, in lab-based poker play, testosterone levels in winners and losers alike rose approximately 10% in 25–30 min of competition (Steiner, Barchard, Meana, Hadi, & Gray, 2010). The magnitude of testosterone change in response to competition may also condition subsequent competitive behavior (Mehta & Josephs, 2006; Zilioli & Watson, 2014).

Relatedly, Casto and Edwards (2016) reviewed research on cortisol responses to human competition, as well as a smaller number of studies that have measured DHEA and androstenedione responses to competition. Findings showed that athletic competition typically led to an increase in cortisol levels, in some cases with elevated levels among winners relative to losers. Context and individual factors such as motivation also mattered, with cortisol findings less consistent in lab settings. McHale et al. (in review) extended the scope of human non-athletic competition and hormone responses to children in Hong Kong, finding that 8–10 year old boys and girls competing in a math competition had decreases in cortisol but no change in DHEA or androstenedione levels. According to the dual hormone hypothesis, testosterone responses to competition are contingent upon low vs. high baseline cortisol levels (Mehta & Prasad, 2015).

Several studies have investigated hormone responses to video gaming. Anticipatory changes in hormone levels before the start of a ping-pong video game match were observed (Mazur et al., 1992). Effects on testosterone and cortisol of playing a violent, multiplayer video game showed that individuals who made the most effort towards their team's victory had an immediate increase in testosterone after the match, whereas the losing team's most active team members faced a delay in testosterone increase, but only if this competition was played before the within-group tournament (Oxford, Ponzi, & Geary, 2010).

Here, we test hormone responses of young men playing League of Legends, a multi-player online battle game thought to activate male coalitional competitive psychology. The study involves men playing in a group of 5 against other groups of 5 players (condition 1) and a control condition playing against the computer (artificial intelligence, or AI). The study has several merits. It is the first to test potential hormone responses of playing League of Legends or any other esport. The study entails measuring a wider array of hormones—testosterone, cortisol, DHEA, androstenedione, and aldosterone—than is typically the case in the literature, and by arguably the gold standard (mass spectrometry) of methods. The inclusion of aldosterone, a hormone involved in water balance and blood pressure, may add novel insight into physiological responses to non-athletic competition. The study also involves testing a potential role of individual experience and performance. We hypothesize that steroid hormones will increase during the competition, with relatively higher increases when playing humans vs. the computer. We also hypothesize that winners will have greater increases than losers in these responses, with potential moderation of hormone change based on performance.

2. Material and methods

The study was conducted at the University of Nevada, Las Vegas (UNLV), in the U.S., in a computer lab facility. The players were male members of a campus esports club. All testing sessions took place on Friday afternoons during regular gaming club meetings. Two test sessions involved teams of players ($n = 26$) competing in groups of 5 against another team of 5 players. Two test sessions, serving as within-subject controls, involved 17 of the same subjects competing in teams of 5 players against the computer (AI). Play against other people and against the computer took place on different Fridays. Players not participating in the study were also allowed to compete, accounting for why numbers of players were not straightforward multiples of five teammates. Only one individual began play against people but dropped out, resulting in 26 (rather than 27) participants, whereas nine individuals did not participate in play against the computer. The study was approved by the UNLV Institutional Review Board.

Subjects provided 2–3 ml of saliva by passive drool. Saliva collection is considered minimally invasive, and has other advantages for purposes of this study: steroid hormone levels in saliva are highly correlated with blood levels; many subjects prefer to provide saliva over venous blood draws; multiple samples can be obtained in a relatively short span of time (which is more difficult for urine samples); and for some participants hormone responses could be altered by blood draws (e.g., cortisol responses to the stressor of a blood draw) (see Gray, McHale, & Carré, 2017). Samples were obtained before play began and within 10 min after play concluded. Play lasted 15–27 min. At the conclusion of play, subjects answered questions about sociodemographic characteristics and play in a brief survey. Play experience was assessed by number of ranked games previously played and experience- and skill-based rank converted to a 1 (little) to 5 (high) measure. Self-rated performance on a 1 (poor) to 5 (high) scale and the ratio of kills-to-deaths (higher ratios for better performance) served as performance measures. Saliva samples were stored in a −20C freezer within 2–3 h of collection until shipped to ZRT Laboratory for assay.

Saliva samples were assayed by ZRT Laboratory using liquid chromatography–tandem mass spectrometry (LC-MS/MS). All intra- and inter-assay CVs were <18% over the reportable linear ranges for testosterone (3.0–5100 pg/ml), DHEA (17–1900 pg/ml), androstenedione (1–2300), cortisol (0.1–80 ng/ml), and aldosterone (3–560 pg/ml). Several aldosterone levels fell below assay sensitivity, with these assigned half the value (1.65 pg/mL) of that sensitivity limit. All analyses were conducted with SPSS v 23.

3. Results

A total of 26 players 18–23 years of age participated in the game condition, with 17 of these same participants also participating in a control condition playing against the computer. The average age of players was 20.46 years (SD = 1.42). The average of ranked player games was 301.28 (SD = 437.60). The average composite experience- and skill-based rank was 2.73 (SD = 1.40). Raw hormone data are provided in Table 1.

K–S tests showed that DHEA, cortisol and aldosterone levels were not normally distributed and were thus log transformed. All analyses relied upon before levels subtracted from after levels. Percent hormone change is also presented in Table 1, and reflects before levels subtracted from after levels, with the resulting number divided by before levels and multiplied by 100. One-sample t tests indicated that only aldosterone decreased, both during play against humans, $t\ (25) = -2.57$, $p = .016$, and the computer, $t\ (16) = -3.45$, $p = .003$. All other hormones did not change, either during play against humans or the computer. The results of these null t-tests are provided in the Appendix. Contrary to expectations, testosterone, cortisol, DHEA, androstenedione and aldosterone did not increase more in the human play condition compared to the control AI condition, as also shown in the Appendix. No differences in hormone change based on winning/losing were observed (only tested against people because players universally defeated the computer).

In exploratory analyses, duration of play against other people (which ranged between 16 and 27 min) was positively correlated with increases in testosterone ($r = .410$, $n = 26$, $p = .037$), DHEA ($r = .461$, $n = 26$, $p = .018$) and androstenedione ($r = .421$, $n = 26$, $p = .032$) but not cortisol or aldosterone. The only other significant exploratory finding was that cortisol decreased more in relation to number of ranked games played ($r = .563$, $n = 26$, $p = .003$). Contrary to expectations of the dual-hormone hypothesis, before-play cortisol was not negatively related to testosterone change. Moreover, measures of experience and performance were unrelated to hormone changes.

4. Discussion

The main result from this study is that, contrary to expectations, playing League of Legends failed to change young men's testosterone, cortisol, DHEA or androstenedione levels, or show differences between play against humans compared to a control condition against the computer (AI). We suggest several main factors underlie these null findings. Participants played against familiar club members rather than out-group opponents, with previous work finding greater testosterone and cortisol responses when playing against an out-group than in-group (Flinn, Ponzi, & Muehlenbein, 2012). Although esports play here in a lab represented a naturalistic study (given this is the regular venue for competition), the familiar and informal exhibition setting may be consistent with previous findings that testosterone and cortisol responses to competition are less consistent than in other contexts such as naturalistic sports competition (Casto & Edwards, 2016). In our observations of play, participants seemed to be having fun in a friendly environment with approximately 30–40 club members, predominantly young men, present.

The finding that play duration against people was positively related to testosterone, DHEA and androstenedione change shows the sensitivity of hormone changes to competition parameters. Previous research on hormones and competition suggests that hormone responses may be induced approximately 15 min after the onset and continuation of a competitive bout, but that in meta-analysis increases in testosterone are more likely to occur in competitions longer than 15 min compared to competitions of shorter duration (see Geniole et al., 2017). The relatively short duration of League of Legends play (15–27 min) may thus have impacted the likelihood of detecting a hormone response. The shorter duration of play may have been at the lower end needed to detect hormone changes, and/or duration of play could also be a proxy for intensity of competition, with longer play associated with more challenging and psycho-physiologically engaging play against people. The level of play selected against AI was "easy," which had the effect of yielding comparable, relatively short duration of play against AI as against people. Players universally defeated the AI. These may be reasons why there was no relationship between play duration against AI and hormone changes, unlike play against people.

No previous studies, to our knowledge, have tested potential effects of competition on aldosterone changes (see Kubzansky &

Table 1
Descriptive hormone data (mean ± SD) before and after League of Legend play against people and computer (control).

	Before Match	After Match	% Change Match	Before Control	After Control	% Change Control
Testosterone (pg/mL)	71.9 (21.5)	73.0 (23.6)	2.8 (21.0)	81.9 (28.7)	79.7 (29.5)	−2.9 (13.4)
Cortisol (ng/mL)	2.1 (2.2)	1.7 (1.2)	5.6 (82.1)	2.0 (2.0)	1.5 (1.3)	−1.8 (82.0)
DHEA (pg/mL)	189.4 (113.1)	199.6 (137.0)	8.9 (36.2)	146.6 (76.5)	144.4 (78.1)	4.2 (39.1)
Androstenedione (pg/mL)	75.3 (24.8)	74.2 (22.0)	2.5 (22.7)	75.6 (32.2)	73.2 (29.6)	−1.5 (17.6)
Aldosterone (pg/mL)	20.3 (23.4)	11.7 (12.1)	−9.1 (74.1)	22.7 (19.5)	15.8 (17.4)	−29.2 (74.9)

Note: % Change Match refers to 100 * (After Match − Before Match)/(Before Match). % Change Control refers to comparable percent hormone changes when playing against the computer. The data for % Change Match and % Change Control refer to mean ± SD of individuals' hormone change in those two conditions.

Adler, 2010). Why did aldosterone levels decrease overall, and in both play against people and AI? An interpretation of the decrease in aldosterone with competition is that the shift from ambulatory preparation for play to sitting enables lowering blood pressure and shifting Na/K balance, given that aldosterone is involved in water regulation and blood pressure. The decline is also consistent with an interpretation that play was viewed as informal and fun rather than deeply competitive. This decrease in aldosterone levels during gaming competition contrasts with typical increases observed during vigorous physical activity (e.g., Lösel, Feuring, & Wehling, 2002; Wolf, Nguyen, Dumoulin, & Berthelay, 1986). Some other research on human hormones and competition has observed decreases in cortisol during a competition (e.g., McHale et al., in review; Oxford, Tiedtke, Ossmann, Özbe, & Schultheiss, 2017), with interpretations such as unmeasured anticipatory hormone changes before a baseline measurement or a relatively relaxed competitive outlook potentially accounting for decreases in cortisol. It is notable that the present study showed that patterns of aldosterone and cortisol levels differed, meaning that some global interpretation such as relaxed sitting play cannot account for both hormone responses.

In summary, the present study showed in a naturalistic setting that young U.S. men playing League of Legends exhibited no changes in testosterone, cortisol, DHEA, or androstenedione levels, whether playing against other people or the computer. Aldosterone levels decreased both in play against other people and the computer. In play against other people, the duration of play was positively correlated with young men's increases in testosterone, DHEA and androstenedione. We interpret the generally null nature of these findings as a consequence of play against familiar opponents in a familiar environment. The lack of change in cortisol and decrease in aldosterone suggest play was not experienced as an emotionally-charged stressor but rather somewhat relaxing and of less consequence. The observation of positive correlations between play duration against people and increases in androgens (testosterone, DHEA, androstenedione) could reflect the processes of steroid hormone release (i.e., time required to elicit a measurable response) or the greater competitive psychological effect associated with longer duration play against people. Our results cannot discern a simple interpretation, but do potentially align with the kinds of psychological and logistical considerations highlighted in the existing human research on hormone responses to competition (e.g., Casto & Edwards, 2016; Geniole et al., 2017; Gray et al., 2017).

The present study is subject to limitations, while offering inspiration for future research. The sample size of 26 participants is modest: it is within the range of many naturalistic and lab-based studies of human hormones and competition, although this limits the statistical power to detect potential effects. The sample and environment represented in the present study likely captured a more relaxed and casual form of play given that participants were in an informal, familiar location playing against known competitors. Future research on esports competition (and among fans) might gain by identifying a more salient competition in which to test for hormonal responses (e.g., at a public venue with large viewing audience in-person or online and with financial stakes). The recruitment of different samples of players of varied experience playing esports, including among populations in which esports has a greater public visibility (e.g., urban Korea), would be beneficial and help address how generalizable the present findings may be. Future work might compare aldosterone responses to physical and non-physical (like here) forms of competition, and include games of longer duration given the links observed here between play duration and hormone change. As esports continues to expand at the interface of technical innovation, changing human lifestyles, and human competitive proclivities, more interdisciplinary research is warranted to understand the effects of esport play and viewing.

Appendix 1. Results of t-tests for hormone change during play against people, against the computer (control), and contrasts between play against people vs. computer.

	Play vs. Computer (n = 26)		Play vs. Control (n = 17)		Play vs. Computer vs. Control (n = 17)	
	Difference (mean ± SD)	t statistic	Difference (mean ± SD	t statistic	Difference (mean ± SD)	t statistic
Testosterone (pg/mL)	1.11 (15.18)	.37	−2.12 (8.70)		.55 (17.59)	.13
Log Cortisol (ng/mL)	-.07 (.29)	−1.27	-.10 (.28)	−1.55	.02 (.45)	.20
Log DHEA (pg/mL)	.01 (.16)	.36	-.01 (.16)	-.25	-.00 (.22)	-.01
Androstenedione (pg/mL)	−1.10 (20.36)	-.28	−2.43 (14.04)	-.72	−2.77 (17.80)	-.64
Log Aldosterone (pg/mL)	-.18 (.35)	−2.57*	-.31 (.37)	−3.45**	.55 (17.59)	.97

Note: Differences reflect either log or raw After hormone level minus Before hormone level. One-sample t-tests are used to test whether hormone levels changed during play, and paired t-tests for those participants who played in both conditions. *p < .05 **p < .01.

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