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SHORT REPORT

Salivary steroid hormone responses to dyadic table tennis competitions among Hong Kongese juvenile boys

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Abstract

Objectives: Little is known about salivary steroid hormone responses to dyadic competition among prepubescent boys. The current study explored pre-match and post-match testosterone, dehydroepiandrosterone (DHEA), androstenedione, and cortisol among 22 ethnically Chinese, Hong Kongese table tennis athletes, aged 8-11 years, during dyadic competition against peers. These data provide novel comparative insight into boys' hormone responses when participating in similar forms of competition to that of adults.

Methods: Measures of salivary steroid hormones, age, outcome, and participant's self-reported perceived performance were obtained. Pre-match salivary steroid hormones and competition-induced steroid hormone changes were explored to further assess overall hypothalamic-pituitary-adrenal axis activity.

Results: Cortisol decreased for most participants, whereas testosterone measures were below the sensitivity of the assay. DHEA and androstenedione did not significantly change during the table tennis exhibitions and were unrelated to independent performance variables. Correlational analyses indicated that competition-induced androstenedione and cortisol change were positively related.

Conclusions: Findings show that juvenile boys' steroid hormone responses during dyadic athletic competition differ in comparison to adult males, in whom cortisol and testosterone tend to rise. Lack of significant DHEA and androstenedione change during the table tennis competition differs from our previous work that showed DHEA and androstenedione were sensitive to more physically taxing forms of athletic competition (eg, soccer). These results are discussed in light of potential factors that may have contributed to these differences.

1 | INTRODUCTION

Researchers have investigated acute steroid hormone responses to adult dyadic (one vs one) competition, in which testosterone and cortisol increases are frequently associated with athletic competition, a proxy measure for ancestral male-male competition, and contextual factors, such as match outcome and performance (Casto & Edwards, 2016; Geniole, Bird, Ruddick, & Carré, 2017). Few studies have explored acute steroid hormone responses to competition among juvenile boys, at an age when primary sex steroid production is low (eg, testosterone), with those studies being limited to team rather than dyadic competition (McHale, Chee, Chan, Zava, & Gray, 2018; McHale, Gray, Chan, Zava, & Chee, 2018; McHale, Zava, Hales, & Gray, 2016).

Evidence from the United States and Hong Kong populations suggests that juveniles' acute steroid hormone responses to competition differ from adults. Dehydroepiandrosterone (DHEA) and androstenedione have been shown in boys to be more responsive than testosterone to competition and to vary based on competition (athletic vs nonathletic) and competitor type (eg, peers, out-group opponents)

(McHale et al., 2016;McHale, Chee, et al., 2018 ; McHale, Gray, et al., 2018). In addition, a consistent link has emerged in pre-match and competition-induced adrenal hormone changes among DHEA, androstenedione, and cortisol (McHale, Chee, et al., 2018; McHale, Gray, et al., 2018). These findings highlight pathways for acute adrenocortical hormone biosynthesis during middle childhood competition that are presumed to reflect physical and psychosocial stress but also may interact on neurobiological levels to promote competitive behavior more generally in the absence of testosterone and shift across life history stages (eg, prepubescence vs adulthood).

To better assess the relationship between acute steroid hormone responses during dyadic, athletic competition in prepubescent Hong Kongese boys, we obtained salivary hormone and performance measures during 2 table tennis competitions. Chinese dominance in table tennis worldwide is unmatched and remains a focal sport among Hong Kong youth and adults today (Besnier, Brownell, & Carter, 2018).

2 | METHODS

2.1 | Participants

Twenty-two boys, between 8 and 11 years of age, from 2 Chinese primary schools in Kowloon, Hong Kong, consisting of 14 and 8 participants from each school, competed in 2, back-to-back, table tennis matches against competitors from their own school.

2.2 | Saliva collection

Table tennis exhibitions occurred at 11:00 AM on November 19 and at 8:30 AM on November 23, 2016. Saliva samples were collected in 5-mL polypropylene tubes (VMR catalog #16465-262) before a 10-minute warm-up period and after the second rounds of matches. Salivary samples were stored at −20°C and shipped to ZRT Laboratory.

2.3 | Experimental procedures

Coaches arranged for players to compete in the first round of matches by comparable skill levels. The first player to score 11 points won that game. Each game was decided by a minimum 2-point margin, and the first player to win 2 games won the match. For the second-round matches, winning players from the first round were paired against winning players, and losing players were paired against losing opponents. Each round lasted ~7-8 minutes, totaling ~15 minutes of competitive match play, for a total of ~25 minutes of play (including the warm-up period).

Parent and Child Informed Consent Forms were signed by each participant and a parent. The University of Nevada, Las Vegas and the University of Hong Kong Institutional Review Boards approved the study procedures and protocols.

2.4 | Hormone determination

ZRT Laboratory utilized liquid chromatography-tandem mass spectrometry for hormone analysis. All pre-match and post-match testosterone levels were below the detection limit (<3.2 pg/mL). Thus, no statistical analyses were performed on testosterone. Of note, 6 of 21 pre-match samples (28.6%) and 2 of 21 post-match samples (9.5%) of DHEA were below the detection limit (17.1 pg/mL). Each measure of DHEA below sensitivity was assigned a value that is half the minimum detection limit resulting in 8 values of 8.55 pg/mL. All pre-match and post-match samples of cortisol and androstenedione were detectable. The intra-assay coefficient of variation for all analytes tested ranged from 2.7% to 15.7% over the following hormone concentrations: testosterone (9.8-83.5 pg/mL); DHEA (35.6-567 pg/mL); androstenedione (21.3-343 pg/mL); and cortisol (400-13 700 pg/mL). Inter-assay precision over the same hormone concentrations ranged from 4.3% to 18.7%.

2.5 | Statistical methods

Relationships among steroid hormone measures, body mass index (BMI), and the pubertal development scale (PDS), a self-report measure of pubertal status, were assessed. Participants' PDS scores ($M = 1.5$, range: 1.2-2.2) confirmed no participants had undergone puberty (Petersen, Crockett, Richards, & Boxer, 1988). Age, outcome (0 = lost both matches; 1 = lost one match and won one match; 2 = won both matches), and self-report measure of performance (1 = poor, 5 = excellent) were included as independent variables.

One participant's DHEA pre-match and post-match values were missing from the laboratory results. Four participants' height, weight, and BMI were not recorded. Because of differences in collection times, pre-match (baseline) hormone measures were compared between the 11:00 AM ($n = 14$) and 8:30 AM ($n = 8$) schools, revealing a difference between cortisol levels. Consequently, cortisol analyses were assessed independently for each school, whereas DHEA ($N = 21$) and androstenedione ($N = 22$) analyses comprised the total sample. All pre-match and post-match DHEA and pre-match and post-match cortisol values among the 11:00 AM school sample were non-normally distributed. Wilcoxon signed-rank sum tests and paired-samples t-tests were employed to investigate pre-match and post-match hormone changes. Spearman's rank-order and Pearson's correlations analyzed the relationships among pre-match hormone levels, hormone change, BMI, age, and PDS. Hormone match change (post-match − pre-match) for DHEA and androstenedione and percent change ([post-match − pre-match/pre-match] × 100) for cortisol were utilized as dependent variables to investigate the relationships between hormone change and match outcome (analysis of variance) and self-rated performance (Spearman's correlation). Two "DHEA change" and one "percent change in cortisol" values were excluded as outliers (more than 3.5 standard deviations away from the mean), which normalized the dependent variables. No difference in percent change in cortisol was observed between the two participating schools. Therefore, percent change in cortisol represented $N = 21$.

Given the nature of the data, DHEA, androstenedione, and cortisol values were also analyzed using multi-level modeling techniques (Supporting Information). All tests were two-tailed ($\alpha = 0.05$) and carried out using SPSS statistical software (Armonk, New York).

3 | RESULTS

Descriptive characteristics are provided in Table 1. Correlations among pre-match hormone concentrations, hormone change, BMI, age, and PDS are presented in Table 2.

3.1 | Pre-competition and post-competition hormone change

A Wilcoxon signed-ranks test showed that all 8 participants from the 8:30 AM school and 10 of 14 (one tie) from the 11:00 AM school experienced cortisol decreases during the competition. The 8:30 AM school's median cortisol pre-match ranks (median = 1700.00 pg/mL) were significantly higher than the median post-match ranks (median = 1100.00 pg/mL; $Z = -2.52$, $P = .01$). The 11:00 AM participants' pre-match ranks (median = 600.00 pg/mL) approached a significant decrease compared to the median post-match ranks (median = 500.00 pg/mL; $Z = -1.87$, $P = .06$), whereas DHEA did not significantly change ($P > .05$). A paired samples *t*-test indicated no significant differences between pre-match and post-match androstenedione levels, $P > .05$.

3.2 | Hormone change associations with independent variables

DHEA change, androstenedione change, and percent change in cortisol were unrelated to match outcome and self-reported measures of performance ($P > .05$).

4 | DISCUSSION

This study revealed that cortisol decreased for most participants in a naturalistic, dyadic, moderately physically taxing competitive setting, among a sample of ethnically Chinese, juvenile table tennis athletes. Testosterone levels were unmeasurable. Contrary to expectations, no significant change in DHEA and androstenedione were observed, which differs from the responses revealed during intensive, team-based, athletic competitions among boys (McHale et al.,

TABLE 1 Descriptive characteristics detailing age, BMI, PDS, and salivary hormone concentrations among boys

	Mean (SD)	Minimum	Maximum
Variables			
Age (years)	9.72 (0.86)	8.10	11.10
BMI (kg/m^2)	16.55 (2.63)	13.14	21.18
PDS	1.50 (0.41)	1.00	2.20
Hormone concentrations (pg/mL)			
DHEA pre-match	73.62 (139.23)	8.55	667.50
DHEA post-match	70.98 (109.37)	8.55	514.40
ΔDHEA	−2.64 (46.46)	−153.10	108.90
Androstenedione pre-match	13.02 (7.10)	3.70	30.70
Androstenedione post-match	12.93 (4.76)	3.50	23.10
ΔAndrostenedione	−0.10 (4.42)	−8.60	8.80
11:00 AM school			
Cortisol pre-match	735.71 (607.15)	200.00	2500.00
Cortisol post-match	592.86 (449.73)†	200.00	1800.00
ΔCortisol	−142.86 (606.01)	−1400.00	1500.00
8:30 AM school			
Cortisol pre-match	1600.00 (518.24)	800.00	2200.00
Cortisol post-match	962.50 (399.78)**	400.00	1500.00
ΔCortisol	−637.50 (337.80)	−1100.00	−100.00

Abbreviations: BMI, body mass index; DHEA, dehydroepiandrosterone; PDS, pubertal development scale.
**$P \leq .001$, †$P = .06$ (approached significance).
Pre-match and post-match DHEA and the 11:00 AM pre-match and post-match cortisol sample relied upon Wilcoxon signed-rank sum tests. Pre-match and post-match androstenedione and the 8:30 AM pre-match and post-match cortisol data utilized paired samples *t*-tests. For convention, means, minimum, and maximum values are displayed for all participant data. Note: DHEA data reflect $N = 21$; androstenedione, age, and PDS values reflect $N = 22$; BMI values reflect $N = 18$; cortisol values reflect $n = 14$ (11 AM collection time) and $n = 8$ (8:30 AM collection time).

TABLE 2 Correlations among raw pre-match salivary hormone concentrations (pg/mL), hormone change (pg/mL), BMI, age, and PDS. All pre-match DHEA, DHEA change analyses, and pre-match cortisol and cortisol change data from the 11:00 AM school relied upon Spearman's rank order correlations because of non-normal distributions. All remaining analyses used Pearson's correlations

Total sample	Pre-match androstenedione	ΔDHEA	ΔAndrostenedione	BMI (kg/m^2)	Age	PDS
Pre-match DHEA	0.67**	−0.24	−0.55*	0.31	0.26	−0.13
Pre-match androstenedione		−0.22	−0.75**	0.25	0.15	0.04
ΔDHEA			0.17	0.02	−0.24	0.01
ΔAndrostenedione				−0.40	−0.15	0.10
BMI (kg/m^2)					0.24	−0.16
Age						−0.24

	Pre-match androstenedione	Pre-match cortisol	ΔDHEA	ΔAndrostenedione	ΔCortisol	BMI (kg/m^2)	Age	PDS
11:00 AM school								
Pre-match DHEA	0.74*	0.73*	−0.24	−0.52	−0.61*	0.53	0.16	0.16
Pre-match androstenedione		0.67*	−0.17	−0.68*	−0.66*	0.68*	0.04	0.10
Pre-match cortisol			0.11	−0.66*	−0.82**	0.43	0.09	0.12
ΔDHEA				0.07	−0.07	0.45	−0.02	0.27
ΔAndrostenedione					0.91**	−0.64*	−0.06	0.08
ΔCortisol						−0.77*	−0.06	0.05
BMI (kg/m^2)							0.16	−0.17
Age								−0.13
8:30 AM school								
Pre-match DHEA	0.61	0.68	−0.14	−0.61	−0.65	0.07	0.29	−0.76
Pre-match androstenedione		0.52	−0.11	−0.95**	−0.65	−0.21	0.31	−0.05
Pre-match cortisol			−0.54	−0.62	−0.78*	−0.19	0.31	−0.38
ΔDHEA				0.46	0.25	−0.29	−0.43	−0.40
ΔAndrostenedione					0.74*	0.06	−0.35	0.18
ΔCortisol						0.04	−0.40	0.62
BMI (kg/m^2)							0.34	−0.15
Age								−0.37

Abbreviations: BMI, body mass index; DHEA, dehydroepiandrosterone; PDS, pubertal development scale.
*P < .05 (two-tailed), **P ≤ .001.
Total sample values reflect $N = 21$ for all DHEA values and $N = 22$ for all androstenedione values. The 11:00 AM school reflects $n = 14$ and $n = 8$ for the 8:30 AM school. Cortisol was investigated as independent groups because of the 8:30 AM pre-match cortisol levels being significantly higher than the 11:00 AM levels. Age and PDS values represent $N = 22$. BMI values represent $N = 18$.

2016; McHale, Chee, et al., 2018). Measures of hormone changes were unrelated to match outcome and self-reported performance. Cortisol is a well-known neurosteroid sensitive to psychological (Dickerson & Kemeny, 2004) and physical stressors (Mastorakos, Pavlatou, Diamanti-Kandarakis, & Chrousos, 2005). Observed cortisol decreases in this study may reflect a more relaxed psychological state among competitors during minimally physically taxing table tennis competitions against peers.

Consistent with previous reported findings among boys competing in physically strenuous (soccer) and non-strenuous (math) team competitions (McHale, Chee, et al., 2018; McHale, Gray, et al., 2018), correlational analyses revealed competition-induced androstenedione change and cortisol change, in addition to pre-match DHEA and pre-match androstenedione, were positively related (Table 2). A consistent positive relationship between androstenedione and cortisol change likely reflects physiological responses that are intrinsically tied to the hypothalamic-pituitary-adrenal axis stress response system. The later association between pre-match DHEA and androstenedione likely reflect the characteristic rise of adrenal hormones associated with middle childhood development and adrenarche (Campbell, 2011).

Furthermore, for the majority of table tennis competitors, pre-match cortisol levels and competition-induced androstenedione change were negatively associated (Table 2), paralleling previous findings from athletic and non-athletic competitive contexts (McHale, Chee, et al., 2018; McHale, Gray, et al., 2018). Thus, among juvenile boy competitors, acute androstenedione change may depend upon pre-match cortisol levels, irrespective of the type of competition and in response to physical and psychosocial stress.

Cumulatively, the reported correlational findings contrast with the adult competition and hormone literature, in which competition tends to be associated with cortisol and testosterone increases in men, and where cortisol acts as a moderator of testosterone activity (the dual-hormone hypothesis), especially among men with low cortisol during status-seeking activities, such as dominance and aggression (Casto & Edwards, 2016; Geniole et al., 2017; Mehta & Prasad, 2015). In light of the findings presented here, it would be of interest to investigate whether cortisol and androstenedione exhibit a similar interaction effect among juveniles when competing in status-relevant behaviors and to further explore relationships between baseline and acute adrenal hormone changes and measures of motivation to compete, aggression, and competitive effort during middle childhood.

The adult male competition literature has shown that out-group competition tends to promote stronger acute testosterone responses, whereas testosterone tends not to change when competing against familiar foes (Flinn, Ponzi, & Muehlenbein, 2012; Oxford, Ponzi, & Geary, 2010). Thus, boys competing against peers in a table tennis exhibition, and without spectators, may account for the observed null findings among DHEA and androstenedione pre-match and post-match levels.

Similarly, no changes in DHEA were observed in children during a math competition (McHale, Gray, et al., 2018). Duration and type of exercise have been found to influence the magnitude of DHEA reactivity in adults (Collomp, Buisson, Lasne, & Collomp, 2015). Collectively, our present and previous null findings regarding DHEA change during non-athletic competition suggest that vigorous forms of physical competition and/or longer durations of competitive match play may be necessary to induce significant changes. In the present study, participants only competed for 15 minutes. In addition, the small sample size of participants may have limited the power to detect possible changes. Unforeseen complications in recruitment limited our priori target *n* of 100 for medium effect. Dyadic competition against unknown competitors, in a higher-stakes context, with spectators, such as regional table tennis tournaments against out-group competitors, would provide a complementary experimental design to assess acute steroid hormone responses in juveniles during dyadic competition.

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CONFLICT OF INTEREST

The authors declare they have no conflict of interest with the contents of this manuscript.

AUTHOR CONTRIBUTIONS

Statistical analysis and crafted the manuscript: McHale
Study design and implementation: McHale, Gray, Chee
Data collection: McHale, Chee, Chan
Logistical support: Gray, Zava, Chee, Chan
Edited the manuscript, provided intellectual content, and critical feedback: McHale, Gray, Zava, Chan, Chee

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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