Salivary Cortisol, Testosterone, and T/C Ratio Responses during a 36-hole Golf Competition

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Abstract

The purpose of this investigation was to study the effects of 36 continuous holes of competitive golf on salivary testosterone, cortisol, and testosterone-to-cortisol ratio and their relation to performance in eight elite male collegiate golfers (age 20.3 [± 1.5] years). Thirty-six holes of a 54-hole NCAA golf tournament were played on the first day of the competition. A saliva sample was taken 45 minutes prior to the round and immediately following each hole for a total of 37 samples per subject. Time matched baseline samples were collected on a different day to account for circadian variation. Six-hole areas under the curve (AUC) values were calculated for endocrine measures. Significant ($p < 0.05$) increases were noted for cortisol during competition, however, testosterone did not change during competition compared to baseline. Testosterone-to-cortisol (T/C) ratio was significantly lower throughout the competition compared to baseline measures. Thirty-six-hole AUC testosterone-to-cortisol ratio response was correlated ($r = 0.82$) to 36-hole score. There was a high correlation between pre-round testosterone ($r = 0.71$), T/C ratio response ($r = 0.82$), and 36-hole score. CSAI-2 somatic anxiety was correlated to pre-round cortisol ($r = 0.81$) and testosterone ($r = -0.80$) response. These results indicate a significant hormonal response during 10 hours of competitive golf. Good golf performance (low golf scores) in this competition was related to low T/C ratio ($r = .82$). Additionally, results from this investigation validated CSAI-2 somatic anxiety with physiological measures of anxiety.

Key words
Cortisol · testosterone · golf · CSAI-2 · testosterone-to-cortisol ratio

Introduction

Pfister and Muir [43] describe stress as the physical or emotional influences that disturb homeostasis of the organism and produce psychological and physiological changes in the organism. One endocrine response to stress is increased activation of the hypothalamic-pituitary-adrenocortical axis (HPAA) [16]. Vining et al. [51] observed salivary steroids to be independent of salivary flow rate and to show equilibrium with blood concentration. These and other findings have enabled noninvasive (salivary) measurement of physiological and psychological stress during athletic performance [39].

Serum cortisol concentration may be elevated during and after athletic performance due to anticipation of or response to psychological stressors [3,24,35] or physical exertion of 70% of $\dot{V}O_{2max}$ or higher [11,34]. One previous investigation (basketball players) reported no change in salivary cortisol from baseline to pre-competition [19]. However, other investigators have reported anticipatory cortisol rises prior to competition in tennis players [5], marathon runners [9,21], pistol shooters [20], weight

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lifters [42], and judo fighters [15, 46]. All previous investigations comparing post-athletic competition cortisol to baseline values have noted significant increases [13, 15, 20, 37, 41, 46].

Previous investigators have compared post-competition cortisol responses in winners and losers. Greater increases in cortisol from pre to post-competition have been noted in winners vs. losers [5, 13, 42, 46]. Passelergue et al. [42] also reported a low T/C ratio during competition, significantly lower T/C ratios in winners vs. losers, and a significant positive correlation between pre-competition cortisol response and performance ($r = 0.67$).

Although not typically associated with stress response, rises in testosterone have been associated with increased physical stress, such as short-term maximal exercise [26 – 28, 30], and psychological stress [20, 44]. Higher testosterone has also been associated with mood states such as competitiveness, drive, persistence, and contribution to winning [10, 22].

Investigators have noted increases in testosterone from baseline measures to post-athletic competition in wrestling, pistol shooting, and judo competition [13, 20, 25, 46], while others have reported no change from pre to post-wrestling or judo competition [15, 19, 41, 42]. Several investigators have also reported greater testosterone responses in winners compared to losers [5, 13, 18, 19, 36].

Cortisol promotes breakdown of muscle protein, while testosterone increases protein synthesis [2]. Therefore, T/C ratio is one indicator of anabolic/catabolic balance. Some investigators have suggested T/C ratio as a marker of overtraining and plasma values below $0.35\ 10^{-3}\ nmol \cdot L^{-1}$ or a decrease of the T/C ratio of 30% or more could be an indication of overtraining in aerobic endurance-type activities [1, 4, 7]. Other investigators have not found T/C ratio to be a reliable marker for overtraining [47]. Additionally, T/C ratio decreases as exercise intensity and duration increase, as well as during intense training or competition periods [48].

There is limited research of stress response during competitive golf and its effects on performance. In one investigation, salivary cortisol and self-reported anxiety (CSAI-2) were measured prior to play and after holes 6, 12, and 18 during competition and practice in 15 Professional Golfer's Association (PGA) pros (aged 21 – 25 years). Salivary cortisol was also measured on baseline days. Higher cortisol concentration, heart rate, cognitive and somatic anxiety in competition versus practice was noted, but performance based on cortisol measures could not be predicted. Cortisol response and heart rate were not correlated with anxiety as measured by the CSAI-2 [37].

Another golf-related investigation measured performance and excretion of several neurotransmitters (norepinephrine, epinephrine, dopamine, and serotonin) under play, qualifying, and competition conditions in 12 collegiate golfers. A significant sympathetic nervous system stress response during competition versus practice and different patterns of response for differing skill levels of golfers were noted [31].

Men's NCAA Division I golf teams play 12 or more tournaments each season and tournaments are normally played over two days with 36 holes played on the first day and 18 holes on the second day. The playing of 36 holes in one day was implemented to reduce the number of days of the competition, while maximizing the number of competitive rounds. As golf has become more popular, golf courses are less willing to allow collegiate golfers to take course time away from paying customers. Additionally, universities, coaches, and players strive to minimize time away from class to maximize academic performance and graduation rates. Other amateur golf tournaments, such as the U.S. Amateur Championship, require playing of 36 holes for several consecutive days.

The purpose of this investigation was to study the effects of 36 continuous holes of competitive golf on salivary testosterone and cortisol and their relation to performance in elite male competitive collegiate golfers. A secondary purpose was to relate pre-competition CSAI-2 measures of perceived anxiety to cortisol and testosterone response.

Methods

Participants

Participants were eight NCAA Division I men golfers with the following characteristics: age 20.3 (± 1.5) years; height 178.4 (± 4.5) cm; mass 75.5 (± 9.1) kg; BMI 23.7 (± 1.9); competitive scoring average 76.4 (± 1.2). The Institutional Review Board Committee of the university approved the investigation. Participants were fully informed of the purpose and risks of participating in this investigation and signed informed consent documents prior to testing. Participants were familiarized with sampling and survey procedures one to three days prior to the actual testing.

Data collection procedures

Competition samples were taken during an NCAA Division I golf tournament. Per NCAA requirements, all 80 players (15 teams) carried their own golf bag throughout the competition. The format for starting was a "shotgun" start so all participants started the round at the same time of day on different holes. Pre-competition saliva samples were taken at 7:15 a.m., 45 minutes prior to teeing off on the first hole of the round. During the competition, a saliva sample was taken immediately following each hole for a total of 37 samples per subject during the 36-hole competition. Time between samples ranged from 10 to 25 minutes, with an average time between samples of 16 minutes (Fig. **1**). The competition was in the month of April and the mean outside temperature was 23.3 °C. Baseline samples were collected at the same location within three weeks of the competition to ensure similar temperatures, which varied from 13.3 to 23.3 °C.

One research assistant was assigned to each golfer for the entire 36-hole round. The research assistant carried 36 pre-labeled Sarstedt salivettes (model #D-51588, Newton, NC, USA), stored in a small cooler on ice. Immediately following each hole, the research assistant provided a new salivette to the subject and recorded the time of sample and the exact type and quantity of any food or drink ingested. Additionally, the subject recorded

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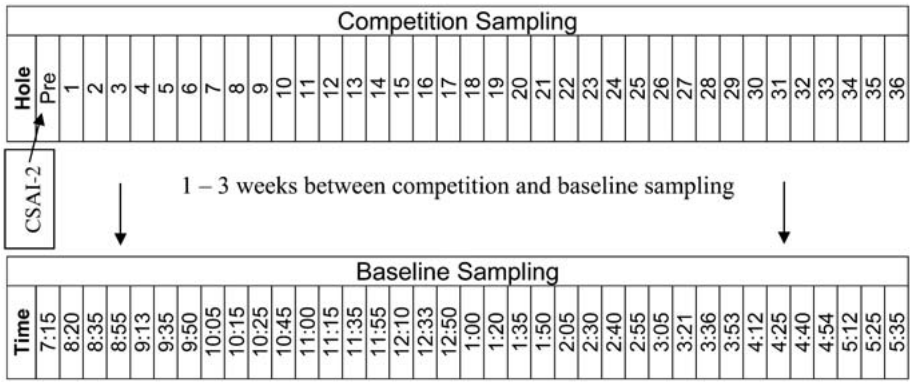

Fig. **1** Saliva sampling procedure. Times are average time for end-of-corresponding hole and baseline sampling.

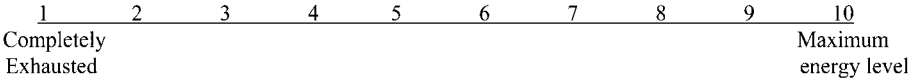

Fig. **2** Fatigue scale. Used after each saliva sampling.

their pre-round dietary intake and their own mental and physical fatigue using a visual analog scale (Fig. **2**).

Participants were instructed to remove and replace the cotton wool swab from the salivette without using their hands and lightly chew on it for 45 seconds. Saliva samples were returned to the laboratory after 18 and 36 holes and centrifuged at 5000 rpm for 10 minutes to force saliva from the cotton swabs into the bottom of the salivettes. Saliva was then transferred to 1.5-mL eppendorfs and stored at – 80 °C for subsequent analysis.

Saliva was thawed and analyzed in the laboratory at a later date to compare cortisol and testosterone concentrations to baseline conditions and performance on the previous and following holes. Baseline saliva samples were collected on a different day within one to three weeks following the competition [24]. Timing of baseline samplings was matched to corresponding time of samplings during competition (Fig. **1**), and reported awakening time was between 6:00 and 6:30 a.m. for all participants in both conditions. The baseline sample was self-collected by each participant on the University campus during normal daily activities. Detailed instructions on data collection procedures were provided to each participant. Physical exercise (other than short, slow walks) and psychologically stressful events were prohibited on baseline days. Additionally, exact timing and type of food and drink consumption were recorded during competition, and this list was provided to each participant on the control day. Participants were instructed to follow the list and exactly replicate timing, type, and quantity of food and drink consumption during the baseline collection. Participants were further instructed to abstain from sexual activity, alcohol, and caffeine the night before and the day of sampling. No deviations from these sample collection, dietary, and activity guidelines were reported by the participants.

Biochemical analysis

Saliva was moved from – 80 °C to – 20 °C 48 hours prior to analysis. Twenty-four hours before analysis, the saliva samples were moved to 0 °C and were allowed to warm to room temperature immediately before analysis. Salivary testosterone concentration was determined in duplicate by enzyme immunoassay using a Salimetrics Salivary Testosterone Enzyme Immunoassay Kit (Catalog No. 1401/1402, State College, PA, USA) with a sensitivity of 0.05 ng/mL. Salivary cortisol concentration was determined in duplicate by enzyme immunoassay using a Diagnostic Systems Laboratories Salivary Cortisol Enzyme Immunoassay Kit (DSL-10 – 671000 ACTIVE, Webster, TX, USA) with a sensitivity of 0.072 µg/dL. Assay plates were read using a 1420 Victor^2 Multilabel Reader (Wallace, Inc., Turku, Finland). Care was used in the preliminary assay set-up to avoid any adverse matrix effect for the salivary concentrations and standard curve displacements. Intra-assay variance for cortisol was 2.51 % and testosterone was 2.69 %. Baseline and competition saliva samples were analyzed in the same batch on the same day.

Competitive state anxiety

Competitive state anxiety was assessed using the CSAI-2. This anxiety-assessment tool separates anxiety into somatic anxiety and cognitive anxiety based on prior research showing the two as distinct components of anxiety [14]. The CSAI-2 also measures self-confidence, and reliability and validity of the CSAI-2 have been reported in depth [33].

Competitive state anxiety was assessed only on the competition day. Forty-five minutes prior to the round, participants completed the CSAI-2. All participants completed a practice CSAI-2 one to three days prior to the competition for familiarization. The CSAI-2 is a 27-item written self-evaluation of state anxiety. The instrument assesses cognitive anxiety, somatic anxiety and self-confidence. Extensive research has been done using the CSAI-2 and it is a reliable and valid psychometric tool [33].

Statistical analyses

Salivary testosterone and cortisol concentration, T/C ratio, as well as perceived fatigue differences were computed by subtracting baseline from competition values to account for individual circadian rhythm variations. These difference values were correlated to performance and CSAI-2 values using a Pearson correlation ($p \leq 0.05$). Each player's 36-hole score was normalized by subtracting a handicap. Handicap was computed by subtracting each player's 36-hole season average score from the tournament average. Tournament average was computed as the mean

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36-hole score of all 80 competitors. Score on each hole was normalized by subtracting a prorated handicap and the average score on each hole of all 80 competitors in the tournament from each individual's hole-by-hole score. Normalization of the scores allows more accurate assessment and comparison of individual performance.

Area under the curve (AUC) values for salivary testosterone and cortisol concentration, as well as T/C ratio, were approximated for the group by summing measures over six holes (6-hole AUC) and over the entire 36 holes (36-hole AUC) during competition and for each corresponding time period during the baseline day. The 6-hole AUC was decided a priori to compare to previous cortisol and competitive golf research [37]. For 6-hole AUC measures, a competition by hole or time period (2×7) repeated measures ANOVA was used to detect any differences between competition and baseline means. Separate baseline and competition data were analyzed using a competition by hole or time period (1×7) repeated measures ANOVA. A Fisher LSD post hoc test was used to determine pairwise differences. Separate hole or time period by competition (1×2) repeated measures ANOVA's were used for pairwise comparison within each time period to determine where specific differences occurred between competition and baseline measures. A Pearson product moment was used to examine the relationship between 36-hole AUC and corresponding golf score. The criterion for statistical significance was set at $p \leq 0.05$.

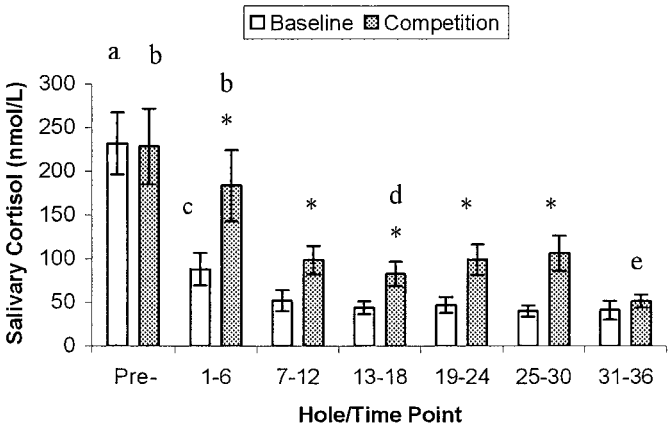

Fig. **3** Salivary cortisol area under the curve (AUC) measures for baseline and competition. Values are means (± SE). * Significant ($p < 0.05$) difference observed between baseline and competition conditions during sample period. [a] Significant difference observed between pre-baseline salivary cortisol all other baseline sample periods. [b] Significant difference observed between competition salivary cortisol sample periods pre- and 1 – 6 and all other competition sample periods. [c] Baseline salivary cortisol at sample periods 7 – 12, 25 – 30 and 31 – 36 was significantly lower than salivary cortisol during sample period 1 – 6. [d] Significant difference observed between competition salivary cortisol sample periods 13 – 18 and 7 – 12. [e] Significant difference observed between competition salivary cortisol during sample period 31 – 36 and salivary cortisol during all other competition sample periods.

Results

Salivary cortisol

Six-hole AUC values were used for statistical analysis. Significant competition vs. baseline effect ($F[1,7] = 4.73$, $p < 0.05$) and a significant hole or time point effect ($F[6,42] = 24.26$, $p < 0.001$) was noted from the ANOVA. No significant interaction was noted between baseline or competition cortisol measures and time of day or hole.

Significant pairwise differences were noted between baseline and competition salivary cortisol measures at sample periods 1 – 6 through 25 – 30 (Fig. **3**). Additionally, baseline salivary cortisol at all subsequent sample periods was significantly lower than the pre-round baseline salivary cortisol. Baseline salivary cortisol at sample periods 7 – 12, 24 – 30, and 31 – 36 was significantly lower than baseline salivary cortisol during sample period 1 – 6. Competition salivary cortisol was significantly lower during sample periods 7 – 12, 13 – 18, 19 – 24, and 31 – 36 than the pre-round and hole 1 – 6 sample periods. Competition salivary cortisol during holes 13 – 18 was significantly lower than competition salivary cortisol during holes 7 – 12. Competition salivary cortisol was significantly lower during holes 31 – 36 than all other sample periods.

Salivary testosterone

Six-hole AUC values were used for statistical analyses. No significant competition vs. baseline effect was noted. However, a significant hole or time point effect ($F[6,42] = 3.65$, $p < 0.003$) was noted from the ANOVA. No significant interaction was noted between baseline or competition testosterone measures and time of day or hole.

Fig. **4** displays significant pairwise differences between pre-round baseline and competition salivary testosterone measures only at sample period 25 – 30. Additionally, pre- and 1 – 6 sample period baseline salivary testosterone were significantly higher than sample periods 19 – 24, 25 – 30, and 31 – 36 baseline salivary testosterone. Also, sample period 1 – 6 baseline salivary testosterone was significantly higher than baseline sample period 13 – 18 salivary testosterone. No significant differences were observed between any sample periods for competition salivary testosterone.

Salivary T/C ratio

Significant competition vs. baseline effect ($F[1,7] = 41.545$, $p < 0.001$) and a significant hole or time point effect ($F[6,42] = 9.85$, $p < 0.01$) was noted from the ANOVA. No significant interaction was noted between baseline or competition T/C ratio and time of day or hole.

Significant pairwise differences were noted between baseline and competition salivary T/C ratio at all sample periods (Fig. **5**). T/C ratio for the baseline sample period pre- was significantly lower than all other sample periods. T/C ratio for baseline sample period 1 – 6 was significantly lower than baseline sample period 19 – 24. T/C ratio for competition sample period pre- was significantly lower than competition sample periods 7 – 12 and 13 – 18. T/C ratio for competition sample period 31 – 36 was significantly higher than competition sample periods 1 – 6 and 25 – 30.

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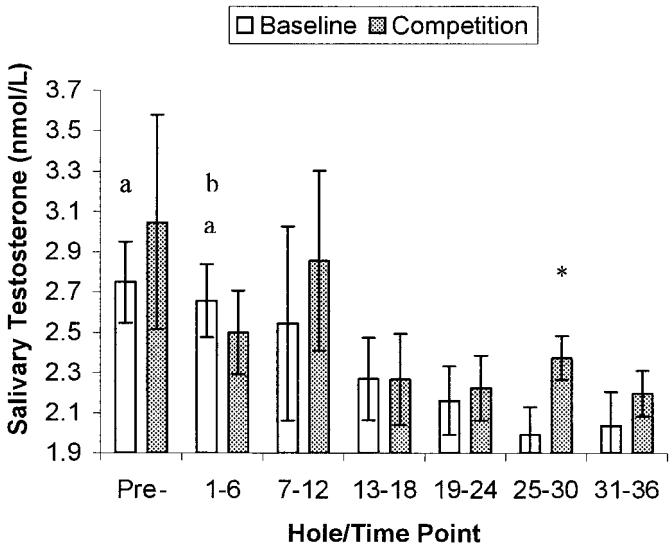

Fig. **4** Salivary testosterone area under the curve (AUC) measures for baseline and competition. Values are means (± SE). * Significant difference observed between baseline and competition conditions. [a] Baseline salivary testosterone was significantly higher than sample periods 19 – 24, 25 – 30, and 31 – 36 baseline salivary testosterone. [b] Significantly higher than baseline 13 – 18 sample period salivary testosterone.

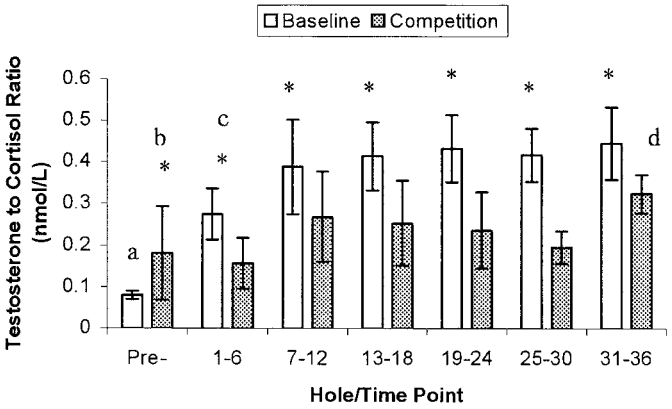

Fig. **5** T/C ratio AUC measures for baseline and competition. Values are means (± SE). A significant ($p < .05$) difference was observed between baseline and competition conditions. [a] Baseline T/C ratio was significantly lower than all subsequent baseline sampling periods. [b] T/C ratio for competition sample period pre- was significantly lower than competition sample periods 7 – 12 and 13 – 18. [c] Baseline T/C ratio significantly lower than baseline sampling period 19 – 24. [d] T/C ratio for competition sample period 31 – 36 significantly higher than competition sample periods 1 – 6 and 25 – 30.

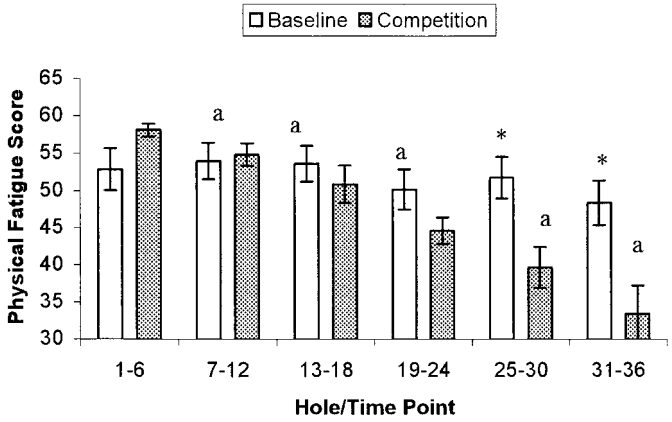

Fig. **6** Physical fatigue AUC measures for baseline and competition. A lower score indicates a greater level of perceived fatigue. Values are means (± SE). * A significant ($p < 0.05$) difference was observed between baseline and competition conditions. [a] Significantly lower than all previous competition time periods.

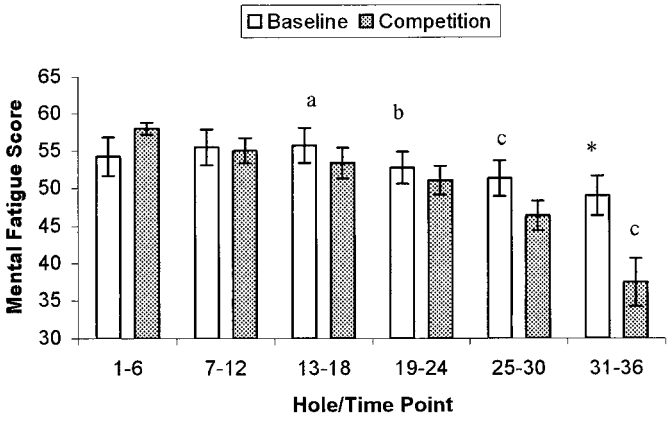

Fig. **7** Mental fatigue AUC measures for baseline and competition. A lower score indicates a greater level of perceived fatigue. Values are means (± SE). * A significant ($p < 0.05$) difference was observed between baseline and competition conditions. [a] Significantly lower than competition sample periods 1 – 6. [b] Significantly lower than competition sample periods 1 – 6 and 7 – 12. [c] Significantly lower than all previous competition time periods.

Perceived physical fatigue

There was no significant competition vs. baseline perceived physical fatigue main effect. However, there was a significant effect ($F[1,5] = 16.57$, $p < 0.001$) of physical fatigue by hole/time period. Additionally, a significant interaction ($F[1,5] = 7.605$, $p < 0.001$) was noted between baseline and competition perceived physical fatigue condition and time of day or hole.

Significant pairwise differences were observed between baseline and competition perceived physical fatigue only at sample periods 25 – 30 and 31 – 36 (Fig. **6**). There were no significant pairwise differences between any baseline perceived fatigue time periods. For competition perceived physical fatigue measures, all sample periods were significantly higher (lower numerically) than all previous competition perceived physical fatigue time periods.

Perceived mental fatigue

There was no significant competition vs. baseline perceived mental fatigue effect. However, there was a significant effect ($F[1,5] = 6.91$, $p < 0.001$) of mental fatigue by hole/time period. No significant interaction was noted between baseline or competition perceived mental fatigue measures and time of day or hole.

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Significant pairwise differences were noted between baseline and competition perceived mental fatigue only at sample period 31 – 36 (Fig. **7**). There were no significant pairwise differences between any baseline perceived mental fatigue time periods. For competition perceived mental fatigue measures, sample periods 25 – 30 and 31 – 36 were significantly higher (lower numerically) than all previous competition perceived mental fatigue time periods. Competition perceived mental fatigue sample period 19 – 24 was significantly greater (lower numerically) than competition sample periods 1 – 6 and 7 – 12. Competition perceived mental fatigue sample period 13 – 18 was significantly greater (lower numerically) than competition sample period 1 – 6.

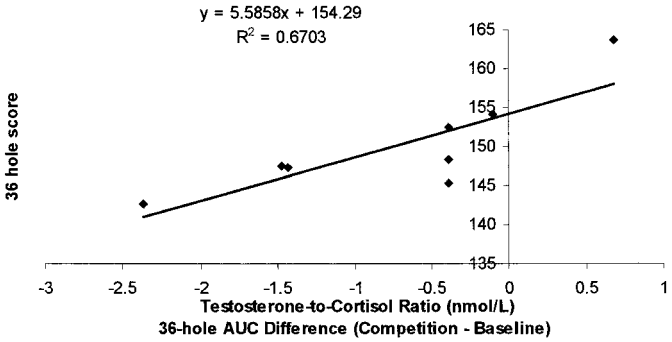

Fig. **8** Net 36-hole score plotted against 36-hole AUC T/C ratio difference (competition minus baseline).

Correlations among measures

Correlations during competition

Pearson product moment correlation coefficients were computed to examine the relationship between 36-hole AUC biochemical measures and normalized 36-hole performance. For cortisol, testosterone, and T/C ratio, differences between competition and baseline measures were summed across all 36 samples to compute one 36-hole AUC value for each biochemical measure per subject. Thirty six-hole AUC T/C ratio difference was correlated with the 36-hole golf score (r = 0.82). Lower 36-hole AUC T/C ratio difference measures were associated with lower 36-hole golf scores (Fig. **8**). There was a positive correlation between 36-hole AUC testosterone (r = 0.68) difference and 36-hole score and a negative correlation between 36-hole AUC cortisol difference and 36-hole score (r = – 0.41). Physical and mental fatigue differences (change from baseline) were positively correlated for the entire 36 holes (r = 0.70) (Table **1**). Correlations were not computed for six-hole increments.

Pre-round correlations

Pearson product moment correlation coefficients were also computed to examine the relationship between pre-round biochemical measures, CSAI-2 components, and 36-hole performance (Table **2**). Pre-round cortisol difference was significantly positively correlated to CSAI-2 somatic anxiety (r = 0.81). Pre-round testosterone difference was significantly negatively correlated

Table **1** Pearson product moment correlations between 36-hole AUC biochemical measure responses, perceived fatigue, and 36-hole performance

	36-Hole performance	*Mental fatigue difference*	*Physical fatigue difference*	*T/C ratio difference*	*Testosterone difference*
Cortisol difference	– 0.41	– 0.65	– 0.68	– 0.51	0.03
Testosterone difference	0.68	– 0.38	– 0.21	0.63	
T/C ratio difference	0.82	0.20	– 0.51		
Physical fatigue difference	– 0.11	0.70			
Mental fatigue difference	– 0.23				

T/C ratio difference = difference between competition and baseline 36 AUC T/C ratio; cortisol difference = difference between competition and baseline 36 AUC cortisol; testosterone difference = difference between competition and baseline 36 AUC testosterone; fatigue difference = difference between competition an baseline 36 AUC perceived fatigue

Table **2** Pearson product moment correlations between pre-round biochemical measures, CSAI-2 components, and 36-hole performance

	36-Hole performance	*CSAI-2*	*Self-confidence*	*Cognitive anxiety*	*Somatic anxiety*	*T/C ratio difference*	*Δ Testosterone*
ΔCortisol	– 0.36	0.39	– 0.57	– 0.10	0.81	– 0.78	– 0.81
ΔTestosterone	0.71	– 0.45	0.16	0.32	– 0.80	0.94	
T/C ratio difference	0.82	– 0.36	0.11	0.39	– 0.72		
Somatic anxiety	– 0.51	0.75	– 0.31	0.02			
Cognitive anxiety	0.61	0.51	– 0.18				
Self-confidence	– 0.15	0.09					
CSAI-2	– 0.17						

T/C ratio difference = difference between pre-round competition and baseline 36 AUC T/C ratio; cortisol difference = difference between pre-round competition and baseline 36 AUC cortisol; testosterone difference = difference between pre-round competition and baseline 36 AUC testosterone

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to CSAI-2 somatic anxiety (r = – 0.80) and significantly positively correlated to 36-hole performance (r = 0.71). Additionally, pre-round cortisol difference was negatively correlated (r = – 0.81) to pre-round testosterone difference. Competition T/C ratio difference was negatively correlated to CSAI-2 somatic anxiety (r = – 0.72) and positively correlated to 36-hole performance (r = 0.82). A lower performance score meant a better golf performance, so higher pre-round T/C ratio difference and testosterone difference measures were related to worse golf performance.

Discussion

To our knowledge, this is the first investigation examining testosterone or cortisol responses during an actual extended championship golf competition. Most investigations have reported pre- and post-endocrine measurements and related them to following or preceding performance. Thus, this study provides unique insights into actual physiological and psychological stress in the game of golf. The primary finding in this investigation was a significant elevation in salivary cortisol in competitive golf compared to a baseline condition and no significant changes in salivary testosterone from the baseline to competitive golf condition. This resulted in a significant decrease in T/C ratio throughout the competition. A high positive correlation (r = 0.82) between 36-hole AUC T/C ratio and 36-hole score was also noted. Additionally, there was a high positive correlation between pre-round testosterone (r = 0.82), T/C ratio (r = 0.71) response, and 36-hole score. Lastly, there was a strong positive correlation between CSAI-2 somatic anxiety and pre-round cortisol response (r = 0.81) and a strong negative correlation between pre-round testosterone (r = – 0.80) and T/C ratio (r = – 0.72) and CSAI-2 somatic anxiety.

Salivary steroid values of participants in this investigation are similar to previously reported values. Baseline salivary testosterone values in this investigation averaged across participants and sample periods (0.38 nmol · L^{-1}) are comparable to values reported for 100 male college students (0.34 nmol · L^{-1}) [10]. Early morning (38.6 nmol · L^{-1}) and evening (6.1 nmol · L^{-1}) baseline salivary cortisol values in this investigation averaged across participants are comparable to previously reported early morning (25.5 nmol · L^{-1}) and evening (6.1 nmol · L^{-1}) baseline salivary cortisol values reported for 100 male college students [51]. Additionally, cortisol values for baseline and competition exhibit a normal circadian pattern, with afternoon samples being lower than morning samples [24].

Salivary cortisol and testosterone response during competition

Salivary cortisol measures during 36-holes of competitive golf (19.0 nmol · L^{-1}) were significantly elevated an average of 111 % from baseline (9.0 nmol · L^{-1}) salivary cortisol measures. McKay et al. reported a similar elevation in cortisol response during competitive golf [37]. Results from this investigation confirm the finding that competitive golf is a significant activator of the HPAA. Elevations in cortisol serum concentration have been noted in anticipation of, or response to, psychological stressors [3,24,35] or physical exertion of 70% of $\dot{V}O_{2max}$ or higher [11,34]. Investigators report golf to require physical exertion of only 35 % to 41 % of $\dot{V}O_{2max}$ [38]. Therefore, any elevation in cortisol during golf performance may be presumed to be the result of psychological or competitive stress.

Ideally, other markers of physiological strain, such as blood glucose and heart rate, would have been measured. However, this study was conducted during an actual competition and the nature of the competition would not allow for invasive data collection and noninvasive methodologies for these markers were not available to the investigators. Given this limitation, we can make some predictions based on dietary data and previous research. Murase et al. estimated the caloric cost of 18 holes of golf to be 960 kcal or 1920 kcal for 36 holes [38]. The average food intake for each golfer in our study was 1787 (229) kcal. Caloric intake was estimated based on the caloric content of the foods ingested for the day. Therefore, a small percentage of the increase in cortisol found in this study may be due to a minor energetic strain.

Salivary testosterone was elevated in competitive golf (0.42 nmol · L^{-1}) vs. baseline (0.39 nmol · L^{-1}), although no statistically significant competition vs. baseline effect was noted. The only statistically significant pairwise difference between competition (0.40 nmol · L^{-1}) and corresponding baseline (0.33 nmol · L^{-1}) values was for holes 25 – 30. This increase in testosterone late in the round may have been due to increased aggressiveness or competitiveness to complete the round successfully [46]. Investigators have noted increases in testosterone from baseline measures to post-athletic competition in wrestling, pistol shooting, and judo competition [13,20,25,46], while others have reported no change from pre- to post-wrestling or judo competition [15,19,41,42]. Interestingly, all investigations reporting rises in testosterone from pre- to post-competition measured serum testosterone, while those reporting no change measured salivary testosterone. This may reflect differences between serum and salivary biocompartments under these competitive conditions and should be studied further.

Pre-competition salivary cortisol and testosterone response

Contrary to our hypothesis, pre-round cortisol measures were not significantly elevated from the baseline to competitive golf condition. These results agree with only one previous investigation with basketball players [19]. Contrarily, many previous investigators have reported anticipatory cortisol rises prior to competition in tennis players [5], marathon runners [9,21], pistol shooters [20], weight lifters [42], and judo fighters [15,46]. A possible explanation for this disparity in results is the early (7:15 a.m.) pre-round sampling time used in this investigation, the long time period before competition (45 minutes), or the presence of an unknown stressor in the corresponding baseline sample. Investigators have linked the daily cortisol secretion pattern to awakening time and report peak secretions at 30 minutes after wake up [12]. Although sample times were identical, subject's wake-up time was not controlled and they may have awakened earlier on the competitive day, thus providing for a longer wakeful time prior to sampling, possibly reducing the first competition-day cortisol sample. A very high first baseline sample (38.6 nmol · L^{-1}) was observed compared to the next baseline sample (15.7 nmol · L^{-1}). A more expected comparison ($p < 0.05$) results when comparing first-hole competition sample mean (32.9 nmol · L^{-1}) to the corresponding baseline sample mean

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($15.7\ nmol \cdot L^{-1}$). A similar result was reported in marathon runners. One hour prior to the race, competition and baseline cortisol were not different. However, immediately prior to the race, salivary cortisol was significantly elevated compared to time-matched baseline cortisol [9].

Golfers in this investigation did not exhibit a significant anticipatory rise in salivary testosterone. Similarly, testosterone did not rise prior to wrestling [25,41], judo competition [15], or skydiving [6]. However, several previous investigators noted anticipatory testosterone rises prior to competition in tennis players [5], marathon runners [9], pistol shooters [20], and judo fighters [46]. Additionally, anticipatory rises were reported during a chess competition only in winners [36]. Loser's testosterone did not rise prior to the match. The rationale for this disparity in the results is unknown.

There may be some specific reasons for the failure of testosterone to rise in the anticipation of competition in this investigation. Possibly sample time was too long before the competition (45 minutes) or golf requires a different mood state since there is not a direct opponent or face-to-face competition in golf. Most of the previous findings of an anticipatory rise in testosterone were during face-to-face competition. A sport like golf where an individual is competing for a score against an entire field of opponents may elicit a different hormonal response.

Salivary T/C ratio

T/C ratio has been shown to be one indicator of anabolic to catabolic hormone status or training intensity, and some investigators have suggested T/C ratio as a marker of overtraining. T/C ratio plasma values below $0.35\ 10^{-3}\ nmol \cdot L^{-1}$ or a decrease of the T/C ratio of 30% or more could be an indication of overtraining [1,4]. Although T/C ratio has been developed by some investigators as a marker for overtraining following exhaustive physical training, it may be valuable as an indicator of overstrain during psychophysiological stress. Authors recommend limiting high intensity exercise and competition to avoid overtraining syndrome [47]. Salivary T/C ratio values for individual participants in this investigation ranged from $0.60 \times 10^{-3}\ nmol \cdot L^{-1}$ to $0.23\ nmol \cdot L^{-1}$ in competition. However, for almost 10 hours of the day, golfers' T/C ratios in competition ($0.026\ nmol \cdot L^{-1}$) were an average of 45% below baseline T/C ratio values ($0.048\ nmol \cdot L^{-1}$), which indicates a high level of hormonal strain. Passelergue et al. [42] also reported a low T/C ratio during wrestling competition.

In a recent review article, authors suggested endurance overtraining and chronic psychological stress to have similar effects [8]. Authors warned the synergistic effects of psychophysiological and physiological stress might have detrimental effects on the immune system. Further research is required to assess the effects of this prolonged hormonal strain on fatigue, recovery, subsequent performance, immune function, and long-term health.

Perceived mental and physical fatigue

The golfers' perceived physical and mental fatigue exhibited a similar pattern in this investigation. The only pairwise differences that occurred between baseline and competitive golf conditions were at holes 25 – 30 and 31 – 36 for physical fatigue and holes 31 – 36 for mental fatigue. There were no differences by time of day in perceived mental or physical fatigue throughout the baseline day. However, the ANOVA showed a significant interaction between competitive condition and time of sample. Perceived physical and mental fatigue during the competitive golf day exhibit a declining (increasing fatigue) pattern over the last four sample periods. It appears 36 holes of competitive golf, while carrying clubs, is perceived to be more physically and mentally fatiguing than normal daily activities, particularly near the end of the round. The main purpose of including the perceived fatigue measures in this investigation was to relate perceived mental and physical fatigue to endocrine measures and performance; however, there were no significant relationships. Kraemer et al. also reported no correlation between mental or physical fatigue and cortisol response [29].

Correlations among measures

Correlations during competition

Unlike similar previous investigations, this competition was not over, so clear winners and losers could not be identified. Data was collected during the first 36-holes of the competition only. The players had one more 18-hole round the following day to complete the competition. There were no final winners or losers after the first two rounds, however, individuals were able to subjectively appraise their own performance relative to past performances and the rest of the competitive field. Therefore, each individual's performance to this point in the competition could be related to endocrine and perceived anxiety measures.

It is not surprising that testosterone, cortisol, and T/C ratio were not significantly correlated with performance by hole or 6-hole AUC given the day-to-day variation in hormone responses, the complex nature of golf performance, and delayed action from stimulus to salivary hormone appearance. One investigation reported a 20-minute time delay from LH spike to peak rise in blood testosterone secretion [50]. Salivary cortisol concentration peaks 30 to 45 minutes after stimulus and remains elevated for 60 to 90 minutes [23,24]. Therefore, summing the hormone responses across all 36 holes and associating totals to final performance may provide more meaningful results.

Thirty-six-hole performance was negatively correlated with cortisol response ($r = -0.51$) and positively correlated with testosterone response ($r = 0.63$) during the competition. The correlation between T/C ratio and 36-hole performance was higher ($r = 0.82$). Correlations between raw golf scores and endocrine measures were near identical to these correlations with the normalized golf scores. This is further evidence of the homogeneity of these participants' golf ability.

Previous investigators have compared post-competition cortisol responses in winners and losers. Greater increases in cortisol from pre- to post-competition have been noted in winners vs. losers [5,13,42,46]. Passelergue et al. [42] also reported a low T/C ratio during competition, significantly lower T/C ratios in winners vs. losers, and a significant positive correlation between pre-competition cortisol response and performance. The mechanism for this relationship is unknown, however better performers might be more concerned (stressed) about their performance while worse performers may have relaxed or "given up".

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Pre-round correlations

Pre-round cortisol response (competition minus baseline) was highly correlated ($r = 0.81$, $p < .05$) to the somatic anxiety measure of the CSAI-2. Few studies have validated the CSAI-2 with physiological measures of anxiety. Yan Lan and Gill [52] reported no relationship between heart rate and CSAI-2 components, while McKay [37] reported no relationship between somatic anxiety and cortisol response to competitive golf. However, Filaire et al. reported significant correlations between somatic state anxiety, cognitive state anxiety, and cortisol [15]. Similarly, other investigators have reported significant correlations between cortisol response and more general anxiety measures [21,49].

Pre-round testosterone response had a high negative correlation ($r = -0.80$) with somatic anxiety. This relationship has not been previously investigated, but is not surprising since glucocorticoids act directly at the testicle to inhibit responsiveness to luteinizing hormone [45] and chronic stress may cause reductions in testosterone production [32]. Additionally, previous investigators have reported correlations between low testosterone and psychosocial stress [17,40].

Pre-round testosterone response was also highly correlated ($r = 0.71$) to 36-hole performance. A lower performance score meant a better golf performance, so higher pre-round testosterone difference measures were related to worse golf performance. This relationship has not been previously reported, however, when Gonzalez-Bono [19] analyzed participants by outcome, winners had slightly suppressed pre-competition testosterone, while losers showed significant anticipatory rises in testosterone.

Summary and Practical Applications

In summary, during 36-holes of competitive golf, cortisol was elevated and testosterone-to-cortisol ratio was decreased for most of the 10-hour round. This hormonal response may suppress immune function and subsequent performance and should be considered during training and preparation for such events. Higher pre-round testosterone difference and 36-hole AUC T/C ratio difference measures were related to worse golf performance. Mechanisms for this relationship are unclear. High testosterone and aggressive, dominating moods may not be facilitative to golf performance, and better performers may be more activated, stressed or concerned about their performance, reducing T/C ratio throughout the round. Additionally, results from this investigation validated the CSAI-2 somatic anxiety scale with physiological measures of anxiety. This competition was the middle, or third, of five tournaments during the fall collegiate golf season. A different endocrine response to competitive golf may result during earlier or later season tournaments due to changes in anxiety levels or chronic fatigue.

There are few sports where the athletes are engaged in over 10 straight hours of competition such as NCAA Division I golf and other amateur golf tournaments, like the U.S. Amateur Championship. This study is the first effort, known to the authors, to attempt to quantify at least some facet of the physiological and psychological strain of 36 straight holes of competitive golf. It is worthwhile to apply the findings of this study to design future studies and to improve preparation, during competition, and recovery performance management practices.

Disclaimer

The views expressed in this article are those of the authors and do not reflect the official policy or position of the United States Air Force, the Department of Defense, or the U.S. Government.

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