Sleep and Stress Hormone Responses to Training and Competition in Elite Female Athletes

Abstract

Stress hormone and sleep differences in a competition versus training setting are yet to be evaluated in elite female team-sport athletes. The aim of the current study was to evaluate salivary cortisol and perceptual stress markers during competition and training and to determine the subsequent effects on sleep indices in elite female athletes. 10 elite female netball athletes (mean ± SD; age: 23 ± 6 yrs) had their sleep monitored on three occasions; following one netball competition match (MATCH), one netball match simulation session (TRAIN), and one rest day (CONTROL). Perceived stress (PS) values and salivary cortisol were collected immediately pre (17:15pm) and post-session (19:30pm), and at 22:00pm. Sleep monitoring was performed using wrist actigraphy assessing total time in bed (TTB), total sleep time (TST), efficiency (SE%), latency (SL), sleep onset time (SOT) and wake time (WT). Cortisol levels were significantly higher ($p < 0.01$) immediately post MATCH compared with TRAIN and CONTROL (mean ± SD; 0.700 ± 0.165, 0.178 ± 0.127 and 0.157 ± 0.178 μg/dL, respectively) and at 22:00pm (0.155 ± 0.062, 0.077 ± 0.063, and 0.089 ± 0.083 μg/dL, respectively). There was a significant reduction in TST (-118 ± 112 mins, $p < 0.01$) and SE (-7.7 ± 8.5%, $p < 0.05$) following MATCH vs. TRAIN. Salivary cortisol levels were significantly higher, and sleep quantity and quality were significantly reduced, following competition when compared to training and rest days.

Keywords: Sport; gender; exercise performance

Introduction

Sleep is regarded as an important factor for both optimal performance and recovery in athletes (Forndran, Lastella, Roach, Halson, & Sargent, 2012; Sargent, Halson, & Roach, 2014; Simpson, Gibbs, & Matheson, 2016). However, it has been reported that sleep is often significantly reduced on the nights following training and competition (Fullagar, Skorski, Duffield, Julian, et al., 2016; Sargent & Roach, 2016; Shearer, Jones, Kilduff, & Cook, 2015). In one study, looking at a set of 283 elite (individual and team sport) athletes, more than half (52.3%) suffered sleep disturbances following a late training session or competition (Juliff, Halson, & Peiffer, 2015). This reduction in sleep quality and quantity following training and competition is thought to be due to a number of physiological and psychological factors. These may include an increase in core temperature following exercise (Nédélec, Halson, Abaidia, Ahmaidi, & Dupont, 2015), an increase in muscle tension and pain following training and competition (Halson, 2014), a disruption from light and noise or increases in psychological stress and 'social' requirements (Fullagar et al., 2015). However, there are few reports showing objective data that either support these perceptions or compares the training and competition environment athletes encounter.

The effects of competition on the sleep patterns of athletes has been reported in a limited number of studies. In 28 male elite rugby union athletes, sleep was monitored following a reference night and following the night of a match (Shearer et al., 2015). The results showed a significant decrease ($p < 0.05$) in h of total sleep time following the match compared to sleep time on the reference night (6:02 ± 1:27 h vs. 7:04 ± 1:01 h, respectively). Another study in 16 elite male football players assessed the effect of a night match on sleep (Fullagar, Skorski, Duffield, Julian, et al., 2016), showing that sleep duration was

significantly reduced following a night match compared to both a day match (-2:36 ± 0:45 h, $p < 0.01$) and a day training session (-3:07 ± 0:46 h, $p < 0.01$). A similar finding was also seen in 22 elite male Australian Rules football athletes following night time competition (Sargent & Roach, 2016), where there was a significant reduction ($p < 0.01$) in sleep duration following a night match (5:3 ± 0:6 h) compared to the night following a day match (7:4 ± 1:1 h). Interestingly, very few studies have evaluated sleep patterns or interventions in female athlete populations (Juliff, Halson, Hebert, Forsyth, & Peiffer, 2017; Leeder, Glaister, Pizzoferro, Dawson, & Pedlar, 2012; O'Donnell & Driller, 2017), and even less in female team-sport athletes. Leeder at el (2012) reported elite female athletes ($n = 43$) obtain on average 6:56 h of sleep per night. Whether the similar responses to those seen in the other studies are found in female athletes following competition is yet to be determined.

Another area that has been overlooked in the athlete sleep literature is the psychological stress associated with training and competition. Stress is a characteristic aspect of sports competition, regarded as a psychophysiological process, affecting athletes both cognitively and physiologically (Filaire, Sagnol, Ferrand, Maso, & Lac, 2001). Stress is often measured using a combination of perceptual questionnaires and salivary markers such as cortisol, a hormone biomarker widely used to assess athlete stress in a range of sporting environments (Crewther et al., 2013). A study in 12 male judo athletes used cortisol levels to assess psychophysiological stress during competition (Filaire et al., 2001), and reported a significant increase in the hormone ($p < 0.05$) between a rest day when compared to a pre-competition time point for both regional and inter-regional competitions. Cortisol concentrations were also significantly increased at the pre-competition time point in the inter-regional competitions compared to the regional competitions ($p < 0.05$). Similarly, state anxiety, cognitive and somatic anxiety were also significantly higher ($p < 0.05$) in inter-

regional competitions compared to regional competitions. Currently, limited investigations on cortisol responses in female athletes exist, with only one study that has evaluated cortisol and perceived stress during a game and training in 20 first division female soccer athletes (Haneishi, Fry, Moore, Schilling, & Fry, 2007). The results showed a significant 250% increase in cortisol levels following the game compared to the training session. However, the study design did not match the training and competition trials for physical intensity, making it difficult to draw conclusions on whether the differences in cortisol levels between trials were related to physiological or psychological factors.

Netball is predominantly a female team-sport that often includes night-matches at the professional level, making elite netball athletes an appropriate cohort for this current study. Furthermore, previous research has shown that quality of sleep may be a problem in elite female netballers (O'Donnell & Driller, 2017). Therefore, the aim of the current study was to measure different psychophysiological stress markers during a competition day, an intensity-matched training day and a rest day in elite female netball athletes. A secondary aim of the study was to determine the relationship between the psychophysiological stress markers on subsequent sleep indices following the three study days.

Methods

Participants

A total of 10 elite female netball athletes (mean ± SD; age = 23 ± 6 yrs; body mass = 79.8 ± 8.9 kg) volunteered to participate in the current study. Athletes were from the same team and were of international representative standard. The study took place during the in-season competition phase of the netball season, where the team being studied won the

National Championship. All participants provided informed written consent before taking part in this study. Ethical approval for the study was obtained through the institution's Human Research Ethics Committee. All participants completed a menstrual history questionnaire, providing information on their menstrual cycles.

Design

The current study took place over a 7-day period, whereby athletes completed one netball competition match (MATCH), one netball training session (TRAIN), and one rest day (CONTROL). The MATCH and TRAIN took place at the same time of day (18:00) and were of the same physical intensity and duration. Individual intensity and duration for MATCH and TRAIN was assessed and matched through the athlete's average heart rate (Polar Electro Oy, Finland), Rate of Perceived Exertion (RPE -Borg's 6-20 scale) (Alexiou & Coutts, 2008; Foster et al., 2001; Gaudino et al., 2015) and the exact on-court playing duration for each individual athlete. The MATCH condition was performed during one of the early rounds of the competition and was played against one of the top teams in front of a capacity crowd. The TRAIN condition was performed as simulated game-play within a team training session, with no crowd in attendance.

Saliva samples were obtained at 3 time points from each athlete for the MATCH, TRAIN and CONTROL trials; immediately PRE (17:15), immediately POST (19:30) and at 22:00. At each time point athletes rated their perceived stress level (PS), using a visual analog scale (VAS) from 0cm ("low stress") to 10cm ("high stress"), adapted from Rumbold et al. (2013) and Oda and Shirakawa (2014). The athletes were instructed to mark a single vertical line at the point on the VAS continuum corresponding to their current stress level. Sleep was monitored on the nights following the MATCH, TRAIN and CONTROL to assess total sleep

time (TST), sleep efficiency (SE%) sleep latency (SL), total time in bed (TTB), sleep onset time (SOT) and wake time (WT). To control any dietary variables, athletes recorded their meals and drinks using a smartphone application (MealLogger App, Wellness Foundry, USA) for the MATCH day and were instructed to replicate their diet (nutrition and hydration) for the subsequent TRAIN and CONTROL days. Caffeine was abstained from for each testing day.

Sleep Monitoring

Athletes were required to wear a wrist actigraphy device (Readiband, Fatigue Science, Vancouver, Canada) over the duration of the study period to monitor sleep patterns. The raw activity scores were translated to sleep-wake scores based on computerized scoring algorithms (Sadeh, 2011). The Readiband device has been shown to be reliable in a healthy adult population (Driller, McQuillan, & O'Donnell, 2016) and is commonly used in sporting teams as it is more practical and less intrusive compared to polysomnography (PSG) (Dennis, Dawson, Heasman, Rogalski, & Robey, 2016; Shearer et al., 2015). The Readiband device has been validated against the gold standard polysomnography (Dunican et al., 2017). Athletes were instructed to wear the actigraph on their non-dominant wrist (Dennis et al., 2016), continuously for 7 days, with the exception of time spent during on-court training sessions, during competition, or when in contact with water (showering, swimming). Sleep indices were quantified via the Fatigue Science software (16Hz sampling rate: Readiband, Fatigue Science, Vancouver).

Hormone Assesment

At each of the three time points during all three trials, athletes provided a 5-ml saliva sample by passive drool into a sterile plastic tube. Sugar-free gum (Extra, Wrigley’s, New

Zealand) was used to increase saliva flow (Casto, Rivell, & Edwards, 2017; Crewther, Lowe, Weatherby, Gill, & Keogh, 2009), with saliva samples stored at -20°C until required. On the day of testing, saliva samples were thawed to room temperature and centrifuged at 3000 rpm for 15 minutes to remove mucins. Saliva samples were assayed using a highly sensitive Enzyme Linked Immunosorbent Assay (ELISA) for cortisol (Salimetrics, NSW, Australia), following the manufacturer's instructions. Samples were analyzed in duplicate, using 25 μL of saliva per determination and the ELISA had a lower limit of sensitivity of 0.007 μg/dL. The standard curve ranged from 0.012 μg/dL to 3.0 μg/dL, had an average intra-assay coefficient of variation (CV) of 4.2%, and an average inter-assay coefficient of variation (CV) of 8.5%.

Statistical Analysis

Simple group statistics are shown as mean ± standard deviation unless otherwise stated. A Microsoft Excel spreadsheet was used to estimate the mean effects and 90% confidence intervals (90% CI) of all measured variables between trials (Hopkins, 2006). Magnitudes of the standardized effects were calculated using Cohen's *d* and interpreted using thresholds of 0.2, 0.5 and 0.8 for *small, moderate and large*, respectively (Batterham & Hopkins, 2006). An effect size of <0.2 was considered to be *trivial* and the effect was deemed *unclear* if its 90% confidence interval overlapped the thresholds for *small* positive and negative effects (±0.2) (Batterham & Hopkins, 2006). The distribution of all data was tested with the Shapiro-Wilk normality test. A two-way ANOVA was utilized to examine the effect of conditions on salivary cortisol levels and sleep indices, using a Statistical Package for Social Science (V. 22.0, SPSS Inc., Chicago, IL), with statistical significance set at $p \leq 0.05$.

Results

No significant differences were found between MATCH and TRAIN for mean heart rate (148 ± 8 and 145 ± 10 bpm, *d* = 0.26 ±0.57, *unclear*, respectively), RPE (15 ± 2 and 14 ± 1, respectively), or playing duration (matched exactly).

Sleep Variables

The values for the comparison between the MATCH, TRAIN and CONTROL conditions for sleep variables can be observed in (Table 1; Table 3). There was a significant reduction in TST (-1:58 ± 1:52 h, *d* = -1.41 ±0.77, *large*, p=0.008) and SE (-7.7 ± 8.5%, *d* = -0.79 ±0.50, *moderate*, p=0.018) on the night of the MATCH compared to the TRAIN session (Table 1). A significant increase in SL was observed for the night following the MATCH compared to the CONTROL (50.3 ± 58.5 mins, *d* = 0.89 ±0.69, *large*, p=0.045). Although not statistically significant, there was an increase of 28.5 ± 45.3 mins in SL following the netball MATCH compared to the TRAIN session (67.0 ± 51.9 mins and 38.5 ± 29.3 mins, respectively, *d* = 0.89 ±0.82, *moderate*).

Cortisol

Cortisol levels (Fig. 1; Table 2) were significantly upregulated (354%) POST match when compared to PRE match ($p < 0.001$). There was a significant increase in cortisol concentrations immediately POST MATCH compared to POST TRAIN (293%, p=0.003), which was associated with a *very large* effect (*d* = 3.77 ±0.74) and POST MATCH compared to POST CONTROL (345%, *d* = -3.02 ±0.72, *very large*, $p < 0.001$). A significant increase in cortisol concentration was observed at the 10:00pm time point (*d* = 1.13 ±0.35, *large*,

p=0.013) following the MATCH compared to the TRAIN session and a significant increase was observed at 10:00pm between MATCH and CONTROL (*d* = -0.97 ±0.75, *large*, p=0.042).

Perceived Stress

There was a significant increase in perceived stress for the MATCH compared to CONTROL at the PRE time point (Table 2).

Discussion

The current study is the first to assess psychophysiological stress markers during competition and training environments and examine their relationship to sleep indices in an elite female athlete population. The main findings from the study were a significant increase in salivary levels of the stress hormone cortisol immediately following a netball match and at 22:00pm, when compared to the same time points following an intensity-matched training session. Reduced sleep quantity and quality following the match compared to the training session were also observed. These findings provide the first evidence that elite female athletes experience higher psychological stress levels following a match and a reduction in both sleep duration and quality.

The results of the current study are consistent with previous investigations that have examined the stress response differences for a competition and training environment (Filaire et al., 2001; Haneishi et al., 2007). The study in female collegiate soccer players (n=20) assessed the response of cortisol and perceived psychological stress during a game and training (Haneishi et al., 2007). Somatic state anxiety and cognitive state anxiety were both

significantly greater ($p < 0.05$) pre- and post-game compared with training for all subjects. While we found similar results for increases in cortisol concentrations following a match compared to training, the perceptual stress results differed between the two studies. Although these were not statistically significant, the perceptual stress results from the current study showed trends to higher perceived stress PRE and at 22:00pm following the MATCH (5.2 and 3.2 respectively) compared to TRAIN (3.9 and 2.1, respectively). The inclusion of more in-depth perceived stress measurements, such as the 21-item Self-rating Anxiety Scale (SAS) and the Competitive State Anxiety Inventory-2 (CSAI-2), as used by Haneishi et al. (2007) compared to the VAS scale used in the current study, may have resulted in more sensitive measures to determine perceived stress differences.

Although differing through comparison to a rest day as opposed to a training day, assessment of the psychophysiological stress in judo athletes during competition showed similar results to the current study (Filaire et al., 2001). In the 12 male judo athletes investigated, a significant increase in cortisol concentrations ($p < 0.05$) pre-, post-competition for both a regional and interregional competition compared to a rest day were reported. A possible contributing factor in the difference observed at the POST time point between MATCH and TRAIN in the current study, could be the effect of the crowd. Although speculative, the crowd factor may be similar to the heightened pressure and cortisol response of athletes that play at home compared to away fixtures (Carré, 2006). Previous reports have shown that competition typically creates a psychologically stressful environment, with an anticipatory rise in cortisol concentrations pre-competition (Haneishi et al., 2007; Passelergue, Robert, & Lac, 1999). There are several contributing factors to this, such as playing in front of a large crowd and the pressure of performing that may cause the anticipatory rise in cortisol concentrations pre-competition (Arruda et al., 2016). In contrast to this, in the current

study although not significant, athletes rated their PS highest for MATCH (5.2) compared to TRAINING (3.9) at the PRE time point. The saliva sample was taken PRE match when the athletes were in the dressing room before going out to play. Although it is pure speculation at this point, it is possible that if the saliva sample was taken courtside where athletes were exposed to the large crowd, salivary cortisol and perceived stress levels would have been higher.

In regards to sleep, the results of the current study are consistent with and support previous studies that have assessed sleep indices following either competition or training (Eagles, Mclellan, Hing, Carloss, & Lovell, 2014; Fullagar, Skorski, Duffield, Julian, et al., 2016; Oda & Shirakawa, 2014; Sargent & Roach, 2016; Shearer et al., 2015). The current study showed the same trends in sleep indices and *large effects* on sleep following an evening match, with sleep duration reduced to 6:03 h (25% reduction), similar to the reduction to 5:30 h (from 7:40 h on the training day; 28% reduction) reported by Sargent and Roach (2016). However, our study differs to theirs as sleep/wake behavior was compared between a competitive match and a training session under the same conditions (time, duration and intensity), whereas their comparisons were made between matches taking place at both day and night. However, the difference in TST found in the current study (-1:58 h less following MATCH compared to TRAIN) are similar with another investigation (Fullagar, Skorski, Duffield, Julian, et al., 2016), that reported similar differences between a night match and a day match (~ 2:36 h).

It has been proposed that sleep latency following high intensity exercise late at night is extended, through physiological variables such as increases in core body temperature (Sargent & Roach, 2016), mental stimulation and cognitive fatigue (Fullagar et al., 2015).

The physical exertion following late night competition may also cause disruptions to circadian rhythms, in turn causing a phase delay in melatonin production, and delayed sleep onset (Shearer et al., 2015). Another significant finding of the current study was the *moderate to large* reduction in SE following the MATCH compared to both the TRAIN (-7.7%) and CONTROL (-12.7%), which is supportive of the reduction of SE observed following high-intensity exercise prior to bed compared to no exercise in the study by Oda and Shirawaka (2014). The reduction in sleep duration observed in the current study, following the match and training compared to the control day, may be caused by the delay in bedtime due to the timing of the match and training, a point already observed in another study (Fullagar, Skorski, Duffield, Julian, et al., 2016). However, there is little published data on sleep following competition. This is surprising given that periods of sleep loss could potentially compromise the recovery process for those athletes who need to perform to a high standard on a weekly basis (Skein, Duffield, Minett, Snape, & Murphy, 2013). A study by Juliff and collegues (2017) reported significantly longer sleep durations in a six day netball tournament for the top finishing two teams (8:02h) compared to the two bottom ranked teams (7:01h), highlighting the importance of adequate sleep in a competition setting. Therefore, the ability to improve sleep indices following night competition is important, and interventions, such as sleep hygiene education (O'Donnell & Driller, 2017) and relaxation strategies, following a night match may help to improve sleep in athletic populations (Fullagar, Skorski, Duffield, & Meyer, 2016).

A limitation of the current study was that there was only a single testing day for each condition (match, training and control days). Data collected over a season or over multiple games and training sessions would have allowed for a more in-depth knowledge on competition and subsequent sleep indices. A limitation of the current study was the

Readiband device accuracy for measuring sleep latency and sleep efficiency, as caution has been recommended when interpreting these indices (Dunican et al., 2017). A further limitation of the current study was the potential effect of the menstrual cycle phases. Whilst data on menstrual cycles were collected, we were unable to control for these factors, ensuring that testing occurred at the same time of the menstrual cycle for each athlete. Future research should aim to assess any differences in the stress and sleep responses in both match and training environments at different phases of the menstrual cycle.

In summary, the results of the current study indicate that the match environment resulted in *very large* post-match levels of cortisol and reduced sleep quantity and quality when compared to post-training in elite female netball athletes. The findings of this study are novel, in that the physical intensity between match and training scenarios were matched, and suggest that the psychological stress associated with competition may play a large part in the impaired sleep measures. Practitioners should be aware of the extra stress competition elicits, and adequately allow for appropriate recovery in periodised training programs.

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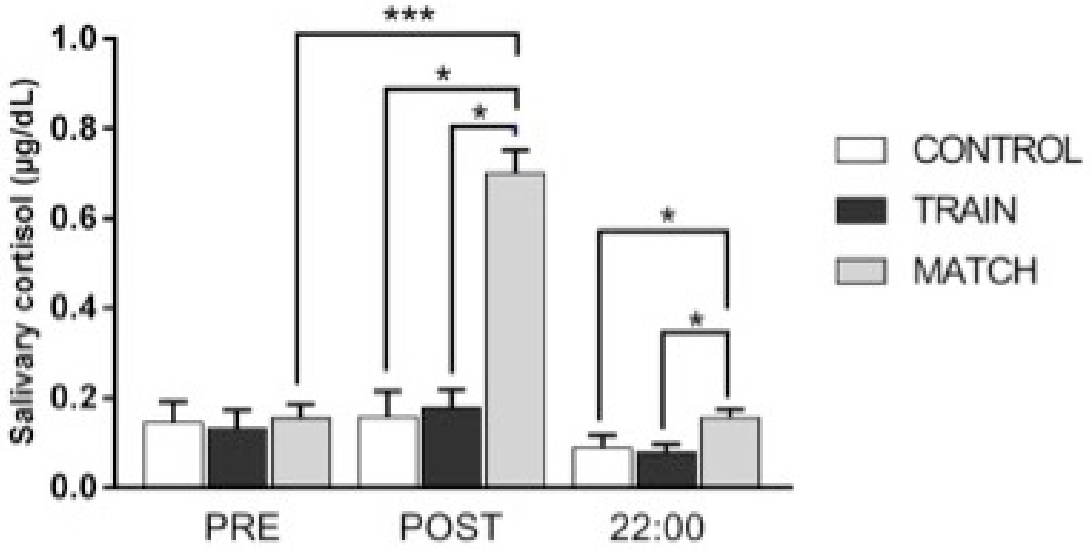

Figure 1 – Salivary cortisol concentrations (µg/dL) pre, post and at 10:00pm for a match (MATCH), training (TRAIN) and rest (CONTROL) day. * indicates a very large effect (Cohen's d) and *** indicates a significant p value <0.001).

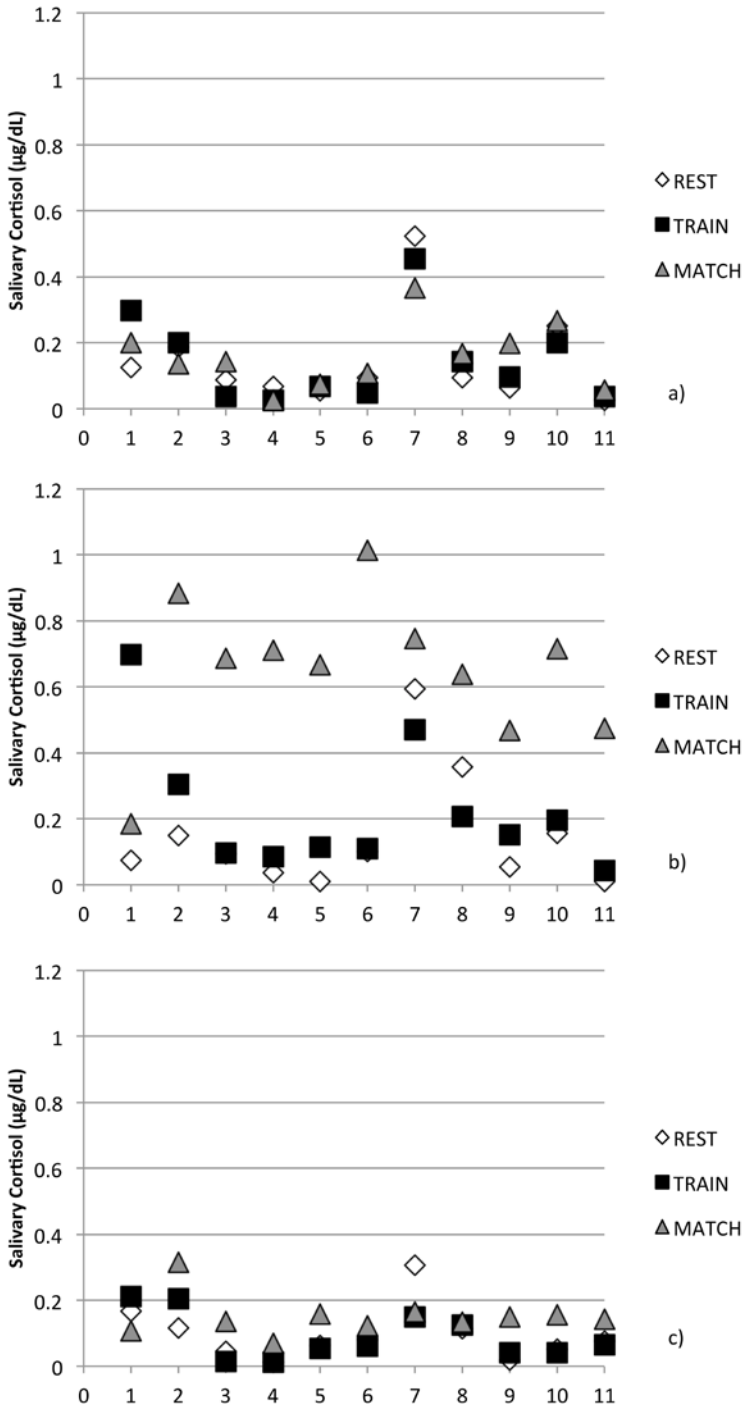

Figure 2 – Examples of individual (*n* = 11) salivary cortisol response (µg/dL) for a) PRE; b) POST; and c) 22:00pm for a match (MATCH), training (TRAIN) and rest (CONTOL) day.