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Original Research

Investigating the Psychophysiological Response to Grade One Muscular Injuries in Professional Australian Football Athletes

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ABSTRACT

International Journal of Exercise Science 15(5): 1052-1063, 2022. The purpose of this study was to examine Australian Football athletes' responses to a grade one muscular injury from a psychophysiological perspective to understand the strength of the association between stress, optimism, and cortisol. Forty-five players listed with one professional Australian Football club volunteered for this study. Inclusion criteria consisted of sustaining a muscular injury during the course of the season with four-weeks predicted recovery time (as diagnosed by club medical staff, n=9). The control group were age, position, and career history matched players from the same sample. Players were also matched for their personality (10-item Big Five Personality Inventory) and fluid intelligence (Raven's Standard Progressive Matrices). Injured players and matched controls completed perceived stress and optimism measures (paper-based questions) as well as salivary cortisol testing once per week for four weeks. Significant increases in cortisol (p=0.015) and perceived stress (p<0.001) were observed in injured players, along with a reduction in optimism (p<0.001) returning by week 4. A significant positive correlation was found between perceived stress and cortisol (r= 0.426), and significant negative correlations observed between optimism and cortisol r= -0.257 and perceived stress r= -0.391. This study showed that athletes were significantly stressed and less optimistic during the first two-weeks of recovery compared to matched controls. While not statistically significant, large effects observed in cortisol and stress in the week prior to returning to competition in the injured group suggest these results demonstrate that a multi-modality approach can improve understanding of psychophysiological stress following a grade one muscular injury in Australian Football athletes.

KEY WORDS: Stress, psychology, team sport, cortisol

INTRODUCTION

While professional sport carries many positive outcomes for the athlete themselves, such as recognition, sense of achievement, and sometimes financial success, injuries experienced in sport can be uncontrollable, overwhelming, and create substantial stress for professional athletes. Sports injuries are generally viewed as being associated with physical consequences, such as understanding the damage to the tissue, the physical pain associated with the injury, and recovery to train and compete. However, there is also a growing interest in the psychological response to injury (25) which suggests, particularly from a theoretical perspective, that there may be a interaction between the athlete and the professional sporting environment (in competition or on training days). While we have a strong understanding of the physical consequences of injury, relatively little is known about how the psychological interaction post injury eventuates (15).

Individuals who experience physical injuries may also experience significant stress and negative psychological outcomes (15). Specifically, within an athlete cohort, the typical emotions experienced due to the occurrence of an injury include stress, anxiety, anger, shock, disbelief, and frustration (25). However, while some athletes view the occurrence of injury as overwhelming and can become debilitated due to this, experiencing feelings of failure and shame (13), others view injury as a challenge and an obstacle to overcome (19). Such differences in the psychological response to injury has been speculated towards the individual's unique stable personality traits and fluid intelligence (the ability to understand and think with complex concepts that, while real, are not tied to concrete experiences) (13). However, far more reflective of an athlete's psychological response to injury are measures of psychological state (e.g., optimistic outlook (33) of athletes) which are more temporary and therefore the focus of this study.

Measures of psychological state are used in professional sport via the utilisation of self-report visual analogue scales (16). While these scales are useful in providing general information on how athletes are psychologically progressing or coping with training on a daily basis to physical preparation staff, there are limitations especially when required to assess the psychological response to injury. In particular, the ability for self-report measures to be manipulated by athletes who choose not to answer honestly for various reasons including, selection issues, concerns around data security and questionnaire fatigue due to over-administration (27).

Understanding the physiological implications of stress as it relates to athlete injury is important, as the consequences can directly affect physical and mental function in all areas of an athletes' life (31). Utilising psychophysiological measures in conjunction with commonly used self-report measures can provide an objective marker of the body's ability to cope and respond to the stress associated with injury, and may aid in improving the rehabilitation process for athletes (23). Within the human body the hypothalamic–pituitary–adrenal axis (HPA axis) releases cortisol, a stress hormone that facilitates action in response to an acute stress or threat (6). Whilst it has been recognized that excessive cortisol release may indicate disease of the endocrine system (e.g. Addison's disease or Cushing Syndrome), mood disorders are also linked with excess cortisol secretion (35). However, understanding the strength of the association between cortisol and psychological states (stress and optimism) in injured athletes is still to be determined. Far less is known about the role of athlete psychophysiological state and injury (26). The psychological stress response of athletes to injury may, in part, be a result of their optimism levels. Optimism is the general tendency to expect positive events in the future (32). Individuals with an optimistic outlook believe life challenges can be overcome and confront adversities with a more active, positive approach, resulting in perseverance and increased success in goal completion (3). There is increasing research within elite athletes that suggests that optimism is associated with an improved ability to cope with stressors including those associated with injury (15). Greater levels of optimism in athletes is associated with a reduced vulnerability to injury and improved injury recovery rates (10), as well as decreased stress levels while injured (15). Given this link between optimism and injury outcome, the ability to maintain an optimistic disposition under stressful circumstances such as injury and the associated rehabilitation process is an area of interest for athletes and high-performance staff. While the association between self-reported stress and optimism has been demonstrated (15), research has yet to explore the links between cortisol and optimism in injured athletes during recovery (29).

The aim of this research was to examine professional athletes' response to grade one muscular injuries from a psychophysiological perspective. Self-report measures of personality and fluid intelligence were used to assess participants for homogeneity and control for any differences between groups. Additionally, cortisol as a physiological marker of stress was assessed, along with self-reported stress and optimism in both injured and non-injured professional athletes. We hypothesised that there would be a significant difference in cortisol, perceived stress, and optimism between injured and non-injured athletes. We also hypothesised that there would be a significant association between cortisol, perceived stress, and optimism.

METHODS

Participants

A convenience sample of 45 professional players employed with one professional club that compete in the Australian Football League (AFL) competition and its affiliate Victorian Football League (VFL) team were invited to participate in the study. Sample size estimation was based on an *a-priori* calculation to detect a moderate effect in stress from injury (f=0.3; 1-β=0.8; α<0.05), requiring a calculated minimum sample size of 16 players (14), allowing us from the pool of 45 to have two groups of eight participants (18). Athletes who sustained a grade one muscular injury (mild damage to individual muscles fibres that causes minimal loss of strength and motion) to any muscle group (11) requiring approximately 4 weeks of predicted recovery (as diagnosed by club medical staff) during the course of the season were eligible for the 'Injury' group (28). The 4-week predicted recovery threshold was used to ensure homogeneity of the sample and maximise the likelihood of observing differences between groups on the identified variables. Subsequent recruitment of an age- and career-matched 'Control' group were obtained from within this convenience sample. Participants were excluded if they were injured at the commencement of this study, were diagnosed with a mental health condition, or had a predicted injury rehabilitation period either under 4 weeks (n = 5) or over 4 weeks (n=7). Participants were required to report any other factors that may have been a confounding variable in altering cortisol levels e.g., medication. In total, 18 participants (nine injured and nine controls) met the eligibility criteria to participate in the study. Personality and fluid intelligence, in addition to salivary cortisol, perceived stress, and optimism were reported by all players at baseline, with subsequent testing completed for cortisol, perceived stress, and optimism for four weeks following an injury in both the Injury and Control groups. The University Human Research Ethics Committee (HEC18041) approved the study. The AFL team gave organisational consent, and participants gave informed consent prior to data collection. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (17).

Protocol

Players completed two paper-based self-report questionnaires about their personality (10-item Big Five Personality Inventory, BFI-10) and fluid intelligence (Raven's Standard Progressive Matrices) prior to the beginning of the 2019 AFL/VFL season. This was to ensure that both the injured and control groups could be matched for personality type and levels of fluid intelligence (9). The 10-item Big Five Personality Inventory (BFI-10) is a shortened version (taking approximately 10 minutes to complete) of the Big Five personality trait measure, assessing the five-factor model of broad personality categories (21). These major personality categories included *openness* (imagination and curiosity), *conscientiousness* (self-efficacy and self-discipline), *extraversion* (excitement seeking, assertiveness), *agreeableness* (modesty and kindness), and *neuroticism* (anxiety and self-consciousness). Items were rated on a scale from '1' (not true at all) to '5' (true nearly all of the time). The BFI-10 has moderate psychometric properties with Cronbach's Alpha coefficients for each category (extraversion: $\alpha = 0.45$; agreeableness: $\alpha = 0.24$; conscientiousness: $\alpha = 0.62$; neuroticism: $\alpha = 0.55$; and openness: $\alpha = 0.36$) (20) (4). To assess fluid intelligence athletes completed the Raven's Standard Progressive Matrices (Raven's) (22). The Raven's is a non-verbal test that consists of 60 multiple-choice questions presented in order of increasing difficulty. Scores range from 0 – 60 with lower scores representing lower levels of fluid intelligence compared to higher scores representing higher levels of fluid intelligence. The Raven's has good psychometric and test-retest reliability (Cronbach's Alpha coefficient: $\alpha = 0.91$) (24).

All eligible athletes (n=45) were instructed to complete two baseline salivary cortisol measures over a three-day period two weeks prior to the beginning of the competitive season (March 2019, during a week of no heavy load physical activity). Following previously published methods (24), each sample was self-collected by the athlete within 15 minutes of waking up, and one day between the first and second sample. For the collection of saliva, participants were required to place the oral fluid collector swab in their mouth on top of the tongue and close their mouth. Participants were instructed to continue swabbing until the indicator on the swab had turned blue in color and 0.5 mL of saliva was obtained. Saliva collection took approximately 30 seconds (8). Scores on salivary cortisol range between 1 and 40 nmol/l (iPro oral fluid collector; Soma Bioscience, Oxfordshire, UK). Using the same methods as in pre-season, injured participants were then required to provide one salivary cortisol sample at the start of every week of prescribed rehabilitation for 4 weeks. Control participants were requested to provide samples at the same time as their matched injured player (24).

Measures of perceived stress and optimism were reported by all athletes at baseline, two weeks prior to the beginning of the season (March 2019). Athletes grouped into either the Injured or Control groups were required to complete these measures for four weeks from the commencement of injury rehabilitation. Stress was measured using the Perceived Stress Scale (PSS), which is intended to capture the degree to which an individual perceives situations in their life excessively stressful relatively to their ability to cope (30). Items are rated on a scale from 0 ('never') to 4 ('very often'). The PSS has good psychometric properties with Cronbach Alpha coefficient α= 0.78 (5). The Life Orientation Test – Revised (LOT-R) was used to measure the level of individual optimism. Items are rated on a scale from A ('I agree a lot') to E ('I disagree a lot'). The LOT-R has good psychometric properties with Cronbach Alpha coefficient α= 0.71 (12). Minimum and maximal measures for PSS were 0 and 40 respectively, while minimum and maximum measures for the LOT-R were 0 and 24 respectively. For each of these measures higher scores represent higher levels of stress and optimism.

Statistical Analysis

Data analyses were completed using Jamovi software (www.jamovi.org). Data were screened for normal distribution. Shapiro-Wilk tests showed normal distribution in cortisol measures (SW range: 0.830 – 0.983; p range 0.107 – 0.964), PSS (SW range: 0.879 – 0.964; p range 0.107 – 0.847), and LOT-R (SW range: 0.828 – 0.9,58; p range 0.102 – 0.801). Measures for BFI-10 and Raven's Standard Progressive were compared between groups using t tests. A mixed-model repeated measures ANOVA with Bonferroni post-hoc was used to compare differences between groups for each dependent variable (cortisol, PSS, LOT-R). Pair-wise comparisons (Cohen's d effect sizes(7)) between groups at each time point were also calculated to complement interpretation of comparisons between groups, (negligible/very small: d<0.20, small: d=0.20 to 0.49, medium: d=0.50 to 0.79, and large: d >0.80). Associations between dependent variables were assessed using Pearson correlation coefficient (small: r=0.1 to 0.3; medium r=0.31 to 0.5; large r>0.51) (1). Alpha was set at ≤ 0.05, and data presented as mean (± SD).

RESULTS

No differences were observed between groups for BFI-10 and Raven's Standard Progressive Matrices at baseline (Table 1). All participants completed baseline and four-week measures of cortisol, PSS, and LOT-R.

Table 1. Big Five Inventory 10 question (BFI-10) and Raven's Standard Progressive Matrices (Raven's) group mean (± SD) responses between injured players and controls pre-injury.

	Control (n = 9)	Injured (n = 9)	t	p	d
BFI-10 Openness	3.20 (± 0.63)	3.50 (± 0.76)	0.911	0.375	0.429
BFI-10 Conscientiousness	3.70 (± 0.67)	3.75 (± 0.71)	0.154	0.879	0.072
BFI-10 Extraversion	3.30 (± 0.67)	3.38 (± 0.74)	0.240	0.813	0.113
BFI-10 Agreeableness	3.40 (± 1.43)	3.25 (±1.16)	0.244	0.810	0.115
BFI-10 Neuroticism	2.80 (± 1.03)	2.50 (± 0.93)	0.645	0.525	0.305
Raven's Progressive Matrices	43.40(± 7.47)	44.13 (± 6.98)	-0.211	0.836	0.100

There was a statistically significant interaction effect for levels of cortisol post injury between control and injury groups ($F_{4,64}$=3.337, p=0.015, Figure 1a). Significant main effects for time ($F_{4,64}$=2.981, p=0.025) and group ($F_{1,16}$=33.200, p<0.001) were observed. Post hoc within-group comparisons for the injured group showed significant increases in cortisol, compared to baseline, in week 1 (t_{16}=3.499, p=0.030; d=1.69), week 2 (t_{16}=3.991, p=0.043; d=1.41), and week 3 (t_{16}=4.075, p=0.040; d=1.57). While still elevated in week 4 (d=1.09), this was not statistically significant compared to baseline (t_{16}=3.011, p=0.373). Pairwise comparisons showed negligible differences between groups at baseline (t_{16}=0.606, p=0.973; d=0.027). However, significant differences and large effect sizes between groups were found in the first three weeks' post injury (week 1: t_{16}=4.84, p=0.008, d=1.884; week 2: t_{16}=4.15, p=0.034, d=1.584; week 3: t_{16}=4.023, p=0.044, d=1.811). Week 4 showed large effect size between groups (d=1.442), but was not statistically significant t_{16}=3.033, p=0.356).

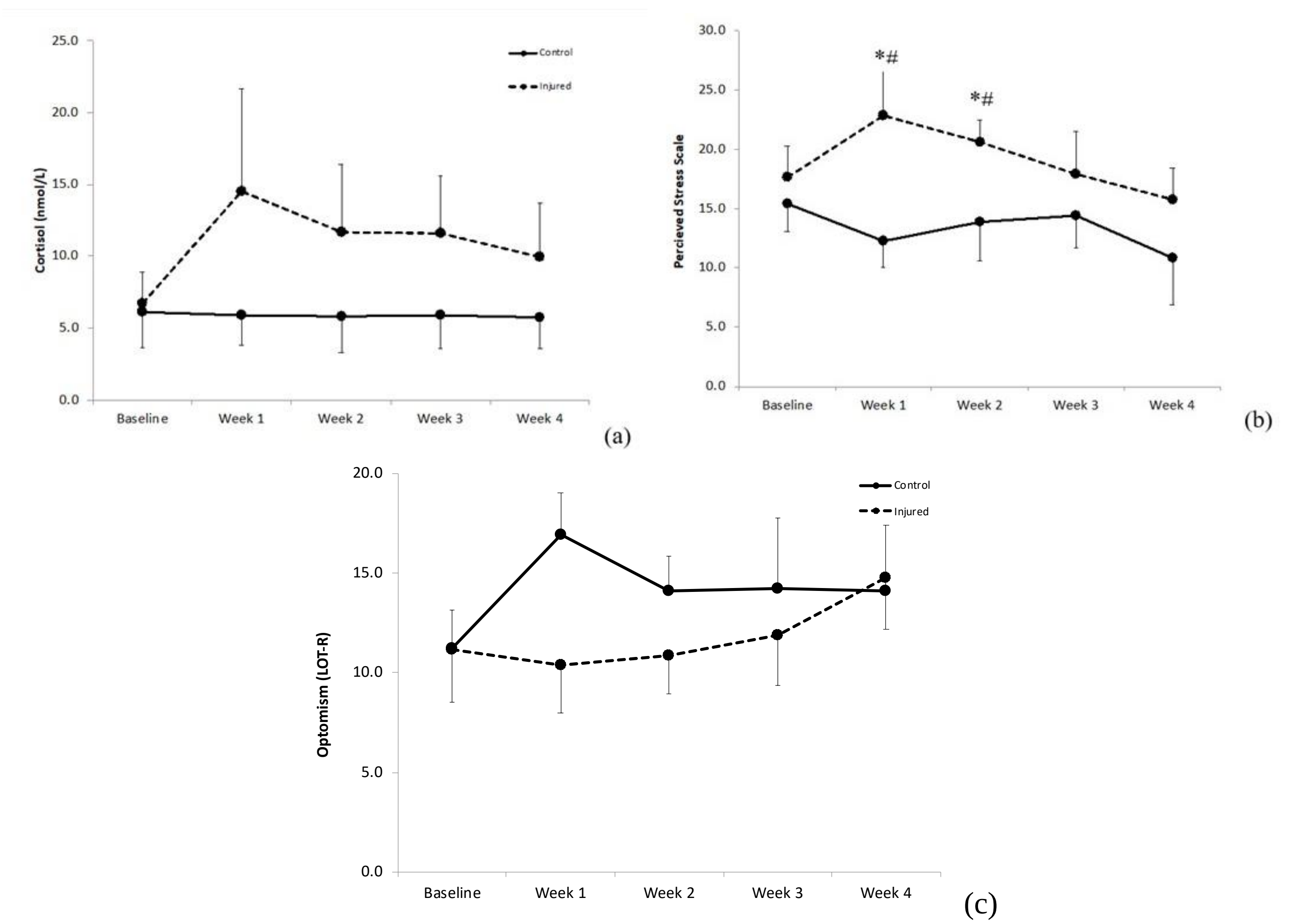

Figure 1 (a-c). Time-course comparison for cortisol (a), perceived stress (b), and optimism (c) between injured athletes (dashed line) and non-injured athletes (solid line). *Significant difference between groups (p<0.05). # Significant difference to baseline (p<0.05).

A significant interaction effect was found for PSS ($F_{4,64}$=6.51, p<0.001, Figure 1b), with main effects also for time ($F_{4,64}$=6.860, p<0.001) and group ($F_{1,16}$=38.90, p<0.001). Post hoc within-group comparisons for the injured group showed significant increase in PSS compared to baseline, in week 1 (t_{16}=5.154, p=0.004; d=1.48) and week 2 (t_{16}=4.129, p=0.035; d=1.34). Differences were not found in week 3 (t_{16}=1.809, p=0.842; d=0.08) or week 4. (t_{16}=-0.241, p=0.978, d=-0.70). Pair-wise post hoc comparisons between groups showed significant differences and large effect sizes between groups for weeks one and two post injury (week 1: t_{16}=6.487, p<0.001; d=3.111; week 2: t_{16}=5.077, p=0.005; d=2.589). While weeks three and four showed large effect sizes, there were no significant difference between groups (week 3: t_{16}=2.322, p=0.585; d=1.093; week 4: t_{16}=3.035, p=0.354; d=1.495).

Significant interaction between groups was found for LOT-R ($F_{4,64}$=8.500, p<0.001, Figure 1c) across all four weeks post injury. Significant main effects for time ($F_{4,64}$=6.38, p<0.001) and group ($F_{1,16}$=8.50, p<0.001) were also observed. Post hoc within-group comparisons for the injured group showed no change in weeks one to three post injury (week 1: t_{16}=-0.782, p=0.816, d=-0.301; week 2: t_{16}=-0.264, p=0.913, d=-0.109; week 3: t_{16}=-0.633, p=0.833, d=-0.293). Week four showed a significant increase and large effect in optimism compared to baseline (t_{16}=4.09, p=0.038, d=1.394). Between group post hoc comparisons revealed significant differences and large effect sizes at week 1 (t_{16}=-6.122, p<0.001; d=2.885) and week 2 (t_{16}=-3.787, p=0.046; d=1.745). While not significant, a moderate effect between groups was observed at week 3 (t_{16}=-2.80, p=0.573; d=0.759), and a small difference at week 4 (t_{16}=3.51, p=0.130; d=0.221) with injured players having higher levels of optimism that control group.

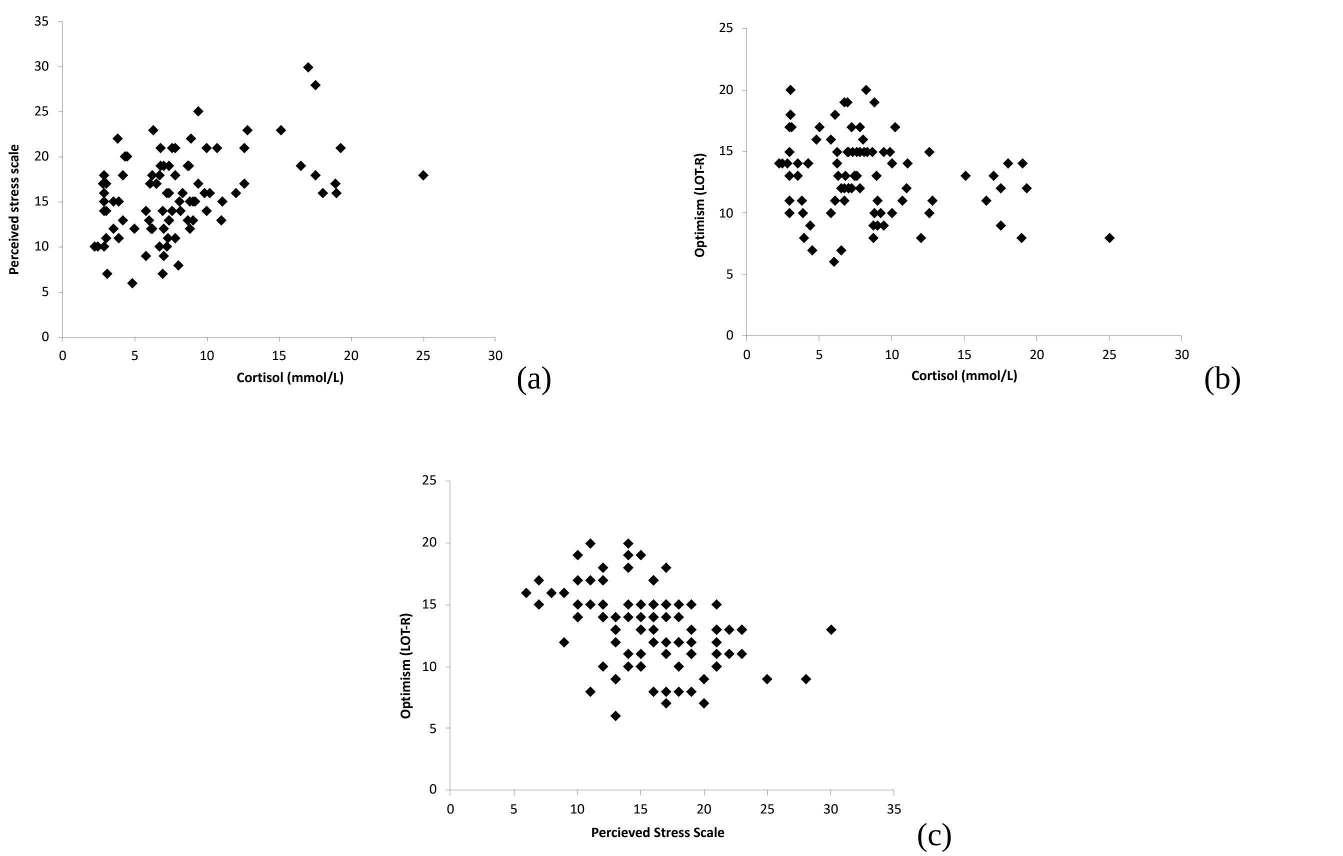

Figure 2 (a-c). Correlations between perceived stress and cortisol (a), optimism and cortisol (b), and perceived stress and optimism (c).

A moderate positive correlation was found between cortisol and perceived stress (r= 0.426, p<0.001, Figure 2a). A small negative correlation was observed between cortisol and optimism (r= -0.257, p=0.014, Figure 2b) and a moderate negative correlation between perceived stress and optimism (r= -0.391, p<0.001, Figure 2c).

DISCUSSION

The aim of this study was to examine the psychophysiological response to grade one muscular injury in professional Australian football athletes. In response to suggestions that self-reporting can be manipulated by athletes who do not want to answer honestly (27), the inclusion of biomarkers such as cortisol allows for objectivity and refinement in psychological stress assessment. Our hypothesis that there would be a significant difference between injured athletes' levels of cortisol, perceived stress, and optimism to non-injured controls was supported. Our second hypothesis that there will be a significant association between cortisol, perceived stress, and optimism was also supported.

No differences were observed between any of the participants on personality traits or fluid intelligence (Table 1). This ensured there was homogeneity between groups allowing for any observed differences to be likely due to stress and not any other extraneous variable. Despite injured athletes self-reporting increased optimism in weeks three and four (Figure 1c) of rehabilitation compared to baseline and increased optimism in week four compared to the control group, they still demonstrated continued stress throughout the first three weeks of their rehabilitation as evidenced by their cortisol levels. With stress playing such an influential role during athlete rehabilitation from injury (2), it is important to acknowledge the importance of a multi-modal approach to assessment utilising both psychophysiological and self-report measures. The addition of a psychophysiological assessment of cortisol identified an additional level of stress experienced by injured athletes that was not recorded by self-report stress assessment

While self-report measures continue to grow in popularity in the sporting setting due to their ease of use and low/no cost, engagement of athletes with these measures is a challenge due to the time it takes to complete and the lack of consistency in which data is captured and utilised (34). While both perceived stress and cortisol were elevated in the two weeks following initial injury, cortisol remained elevated at Week 3, whereas athletes' perceived stress had returned to baseline. This supports the notion that our physiology (e.g. high cortisol levels) are not always reflected in perceptual questionnaires. There is also the possibility of athlete manipulation of self-report measures due to concerns which has been demonstrated in previous research (27), e.g., prioritising accuracy of data over ease of use. To understand the true psychophysiological state of athletes during the recovery process, the incorporation of biomarkers such as cortisol may ensure accuracy of athlete data. Therefore, it is important that high performance support staff employ a multi-modal approach utilising several assessment techniques that cover perceptual and physiological measures when evaluating grade one muscular injury recovery.

The increase in optimism observed in injured athletes by Week 4 is likely due to the type of grade one muscular injury included in this study (4-week recovery). Specifically, the increase in optimism in injured athletes during the last week of recovery may be the point at which the athlete starts to see some positive signs or adaptation and recovery from grade one muscular injury leading to improved optimism levels. However, this time course of change in optimism scores may differ depending on the type and severity of injury. Consequently, this recovery time may not be applicable to athletes with differing levels of injury severity. While results of this study did not demonstrate significant differences between groups at all time points on measures of cortisol, perceived stress and optimism, large and moderate effect sizes were observed between groups where results were not significant (large effect size, cortisol week four, and PPS week three and four and moderate effect sizes for LOT-R week three and four). While this may demonstrate an underpowered sample (despite adequate *a-priori*), these effect sizes illustrate meaningful change between groups at these time points that warrants further exploration. Additionally, those with better optimism show lower cortisol and stress levels, therefore, it is likely beneficial for athletes and high-performance staff to look to improve optimism levels for athletes. This will likely decrease psychophysiological stress and aid in the recovery process form injury.

In this study we used a novel approach to measure athlete stress responses following injury, of which certain limitations need to be considered. First, the correlational nature of this study, while showing significant results, does not allow for a direct examination of the specific causative factors that affect athletes' levels of stress and optimism while injured. Future studies should consider a mixed-methods approach to determine other sources of stress compounding to the athlete's stress from injury. Additionally, cortisol in this study was used to interpret the psychophysiological response to injury, which may also capture stress and anxiety experienced by players about their return to competition evidenced by the somewhat elevated levels of cortisol in week four of recovery even though they were physically recovered. Future studies could incorporate the continuation of assessment into the post recovery phase and include other endocrine factors such as salivary immunoglobin A, which has an important role in immunity and is a non-subjective indicator of stress. While using multiple biomarkers may allow for a more comprehensive understanding of an athlete's stress response as it relates to injury, this can be a barrier for non-elite sporting organisations due to a lack of resources. Future studies could also look to expand the injury inclusion criteria to attain a larger sample for improved power in findings, while employing a mixed methods approach with an increased sample would allow for further exploration into the non-significant large effect sizes observed in this study. A further limitation of this study is the specificity of sample being professional athletes, therefore, the findings of this study may not be generalisable to other athlete populations. While this study employed a strict inclusion criteria (muscular injury with ~4-weeks predicted recovery) to ensure differences in examined variables could be observed, future research could also look at a variety of injury types that may take longer than approximately 4-weeks in duration for recovery.

In conclusion, this is the first study to report associations between cortisol, stress, and optimism in response to a short (4-week) injury in a cohort of professional Australian Football athletes over the course of one season. The time-course changes for cortisol, perceived stress, and optimism across injured and control athletes provide support staff with more detailed insights on how athletes cope with grade one muscular injury during the recovery phase. Of interest is that while athletes may report a more optimistic outlook as time progresses, physiological stress (as observed through salivary cortisol) is still present and may impact on their rehabilitation and performance prior to returning to full competition.

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