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Relationship Between Stress-Recovery State and Running Performance in Men's Collegiate Soccer

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RELATIONSHIP BETWEEN STRESS-RECOVERY STATE AND RUNNING
PERFORMANCE IN MEN'S COLLEGIATE SOCCER

by

NICHOLAS COKER

(Under the Direction of Adam Wells)

ABSTRACT

Purpose: The purpose of this study was to evaluate the relationship between changes in running

performance and the stress-recovery state in Division I collegiate soccer players. **Methods:**

Running performance was evaluated in eight NCAA Division I male soccer players ($179.39 \pm$

5.24 cm; 75.46 ± 5.98 kg; 20.37 ± 1.41 yrs.) over the course of 12 games during a single

competitive season. The 12 games were divided into four blocks [B1(n=3), B2(n=3), B3(n=3),

and B4(n=3)]. Running performance and game load were assessed using a wearable

physiological harness and Global Positioning System (GPS) module. Game load, absolute

distance, and distance covered while engaging in walking (0.2-2.0 m·s^{-1}; 0.72-7.20 km·h^{-1}),

jogging (2.01-3.70 m·s^{-1}; 7.21-13.32 km·h^{-1}), low speed running (3.71-4.99 m·s^{-1}; 13.33-17.99

km·h^{-1}), high speed running (5.0-6.0 m·s^{-1}; 18.0-21.60 km·h^{-1}) sprinting ($6.01+$ m·s^{-1}; $21.61+$

km·h^{-1}), low-intensity running (LIR: 0.2-3.70 m·s^{-1}; 0.72-13.32 km·h^{-1}) and high-intensity

running (HIR: > 3.70 m·s^{-1}; > 13.32 km·h^{-1}) were assessed during each block. These variables

were also assessed relative to minutes played. Stress-recovery state was assessed using the

RESTQ 52 Sport, which was administered to each athlete twice during each block, separated by

at least one week. Measures of general stress (GS), general recovery (GR), sport specific stress

(SSS), sport specific recovery (SSR), global stress (GLS), global recovery (GLR) and the

recovery-stress balance (RSB). **Results:** Total distance was significantly greater during B4

compared to B1 (p=0.027). Absolute jogging distance and low-speed running distance were

significantly greater during B4 compared to all other time points (p's ≤ 0.05). Absolute LIR

distance was significantly greater during B4 compared to B1 (p=0.034). Jog_{rel} was significantly

greater during B4 compared to B1 (p=0.001) and B3 (p=0.001). Analysis of correlation

coefficients between running performance and RESTQ scales indicate that greater high-

speed/HIR is associated with increased stress. Similarly, greater low-speed/LIR is associated

with greater recovery. However, changes in SSR did not correlate with changes in running

performance from B1 to B4. **Conclusions:** The results of this study indicate that running

performance declined across the season. However, changes in performance were not related to

changes in SSR, as determined via the RESTQ 52 Sport questionnaire.

INDEX WORDS: Soccer, Running performance, Stress, Recovery, Global positioning system

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DEDICATION

"The good life is one inspired by love and guided by knowledge."

-Bertrand Russell

I dedicate this thesis to my family, for helping to keep me focused on the big picture and acting as a sounding board whenever I need to regain perspective. For my sister Alex, for being a constant reminder of what hard work and overcoming adversity truly mean. For my sister Haley, for being there from day one to help with issues that others don't always understand and showing me the importance of meticulously honing your craft. For my mom, Mona, for being the unwavering rock that keeps us together, putting family first through both good times and bad, and always being able to cheer me up no matter what may be going on in my life. For my dad, Carl, for teaching me the importance of finding what you love and relentlessly pursuing it, always providing sound, realistic advice, not letting circumstance dictate the person you're going to be, and always picking up the phone when I need you. You are a true inspiration to me.

This dedication could easily include every member of my family. You all support and inspire me every single day. You enrich my life in various, but equally important ways. I could not have done this without all of you surrounding me. I am lucky to have all of you, and love you more than I could ever express.

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CHAPTER 1: INTRODUCTION

The nominal duration of a soccer game is 90 minutes at the collegiate level with a 15-minute half-time break, not accounting for stoppage time. During a competitive game, the ball is typically in play for 52-76 minutes (Tumilty, 1993). Elite players are reported to average a total distance of 11 km over the course of a match, of which approximately 10% is covered at high-intensity (Mohr, Krustrup, & Bangsbo, 2003). Previous research has demonstrated a significant decline in high intensity running performance during the last 15 minutes of a soccer match when compared to the first 15 minutes (Mohr et al., 2003; Silva, Magalhaes, Ascensao, Seabra, & Rebelo, 2013). These reductions in performance are likely due to a myriad of factors, including direct and indirect effects of glycogen depletion, dehydration and contextual match factors (Edwards et al., 2007; Lago, Casais, Dominguez, & Sampaio, 2010; Nielsen, Cheng, Ortenblad, & Westerblad, 2014). Nevertheless, if recovery is inadequate over an extended period of time, non-functional overreaching or overtraining may develop, which could lead to a reduction in performance in subsequent matches (McCormack et al., 2015). Therefore, monitoring the stress-recovery state of soccer athletes appears to be warranted.

Previous research has quantified stress and the associated physiological responses in a variety of ways, including serum and salivary hormonal markers, heart rate responses, and psychological scales (Buchheit, Simpson, Al Haddad, Bourdon, & Mendez-Villanueva, 2012; Coutts, Wallace, & Slattery, 2007; Kraemer et al., 2004; Mallo, Mena, Nevado, & Paredes, 2015; Nunes et al., 2014). Kraemer et al. (2004) assessed changes in hormonal concentrations of testosterone and cortisol in conjunction with sport-specific measures of performance in collegiate soccer players across a 19 game season. Serum concentrations of testosterone and cortisol appeared to suggest that athletes were catabolic for much of the season. Significant reductions in

sprint speed, vertical jump height and peak isokinetic torque (1.05 rad·sec^{-1}) relative to baseline were also observed during the course of the season (Kraemer et al., 2004). However, neither testosterone, cortisol, nor the T/C ratio correlated significantly with performance decrements at any time point. While testosterone and cortisol have been identified as reliable markers of training stress (Hakkinen, Pakarinen, Alen, & Komi, 1985; Hakkinen, Pakarinen, Alen, Kauhanen, & Komi, 1987), these markers may not be may not correspond with changes in performance. Further, these measures are invasive, expensive, and time consuming to perform. Moreover, the use of such invasive measures may also not be feasible during a game situation, due to time constraints, match location and/or the availability of the required resources during away games. Consequently, the use of salivary and/or hormonal markers of stress may not be practical in a number of situations.

Assessment of Heart Rate Variability (HRV) is another commonly used method of assessing physiological responses to periods of increased stress (Buchheit et al., 2012; Pichot et al., 2000). During periods of increased training intensity, autonomic control of heart rate is subject to greater influence from the sympathetic nervous system, which may lead to a decrease in heart-rate reserve, vagal-related indices of HRV, and subsequent performance (Pichot et al., 2000). Decreases in vagal-related HRV indices are generally associated with chronic fatigue, non-functional overreaching and/or overtraining (Borreson & Lambert, 2008; Bosquet, Merkari, Arvisais, & Aubert, 2008). Nevertheless, previous research suggests that baseline vagal HRV indices (square root of the mean of sum of squares of differences between adjacent normal R-R intervals) across a competitive season are not related to changes in performance (Buchheit et al., 2012). Further, HRV is acutely sensitive to factors such as changes in body position, posture and hydration status (Castro-Sepulveda et al., 2015; Kim & Euler, 1997), which are in constant flux

during a soccer match and cannot be standardized from game-to-game. Consequently, while measures of HRV are non-invasive, the use of HRV as an accurate means of detecting changes in stress over the course of a competitive season is questionable.

The use of psychological surveys represents a non-invasive, inexpensive, time efficient means of quantifying the changes in stress and recovery imposed on athletes over time. Psychological surveys that report athlete's subjective feelings of accumulated stress over a given time period have been used previously (Auersperger et al., 2014; Coutts et al., 2007; Lovell, Townrow, & Thatcher, 2010; Meister, Faude, Ammann, Schnittker, & Meyer, 2013). One such instrument is the Profile of Mood States questionnaire (McNaire, Lorr, & Droppleman, 1971). A recent study examining changes in mood among soccer players demonstrated that collegiate and professional soccer players experience greater mood disturbances across a competitive season compared to their lower level counterparts, with greater increases in tension, depression and confusion being evident (Lovell et al., 2010). However, POMS scores are reported to be acutely sensitive to match outcome (winning vs. losing), bringing into question the validity of the POMS in determining true changes in mood state among athletes. Consistent with this, Hassmen & Blomstrand (1995) found no evidence to support the ability of the POMS to predict performance in soccer players.

In recent years, other psychological scales have been developed with the goal of quantifying specific sources of stress and recovery. One such scale is the Recovery-Stress Questionnaire (RESTQ). Significant alterations to somatic components of stress and recovery, as measured via RESTQ, have been reported in response to changes in the average length of daily endurance training sessions (Kellman & Gunther, 2000). Further, RESTQ stress and recovery scales have previously been shown to correlate with serum cortisol concentrations and markers

skeletal muscle damage in highly trained rowers (Maestu, Jurimae, Kreegipuu, & Jurimae, 2006), suggesting that this questionnaire may be a more practical means of monitoring the stress-recovery state over time. Nevertheless, there is currently a paucity of research regarding the relationship between changes in soccer performance and RESTQ subscale scores. It remains unclear whether the RESTQ is a viable means of monitoring stress and recovery across time.

Purpose of the Study

Therefore, the purpose of this study was to evaluate the relationship between running performance and the stress-recovery state in collegiate male soccer players over the course of a regular competitive season.

CHAPTER 2: REVIEW OF LITERATURE

Description of soccer

At the collegiate level, soccer matches are played on a field between 70-75 yards in width and 115-120 yards in length (National Collegiate Athletic Association, 2014). Each team is comprised of a goalkeeper and 10 outfield players, which include defenders, attackers, and midfielders. Distance covered by outfield players over the course of a match are dependent upon several factors, including player age, playing position, and skill level. Contextual factors specific to each match (e.g. strength of opponent, match status, playing location) also appear to play a role (Chmura et al., 2014; Harley et al., 2010; Lago et al., 2010). Nevertheless, elite players are reported to average a distance of 11 km over the course of a match (Mohr et al., 2003). Activity and movement profiles vary widely between individual players across consecutive matches, although a pattern characterized by long bouts of low to moderate intensity activity (e.g. standing, walking, jogging) interspersed with brief bouts of high intensity activity (e.g. sprinting, jumping, tackling, fighting for possession of the ball, etc.) is frequently observed. In elite level players, the combination of high intensity running and sprinting is reported to account for approximately 10% of the total distance covered during a competitive match (Mohr et al., 2003).

Collegiate level soccer matches have a nominal duration of 90 minutes, consisting of two 45-minute halves with a 15-minute halftime break. Over the course of a match, the ball is typically in play for 52-76 minutes (Tumilty, 1993). Participation in an elite-level match may therefore result in a pronounced energy expenditure. The intermittent nature of soccer requires increased energy demand from anaerobic sources. As a result, depletion of skeletal muscle glycogen stores are of primary concern for many soccer athletes during competitive play. Depletion of muscle glycogen may contribute to the development of fatigue (Hermansen,

Hultman, & Saltin, 1967), particularly when glycogen stores are not adequately replenished during competition. Consistent with this, significant reductions in muscle glycogen content have been reported over the course of a competitive soccer match (Leatt & Jacobs, 1989). While the effect of contextual factors such as match location, and game status (e.g. whether a team is winning or losing) on performance cannot be discounted, previous research has indicated reductions in muscle glycogen often coincide with reductions in high-intensity running (Edwards et al., 2007; Lago et al., 2010; Nielsen et al., 2014). These declines are generally accompanied by dehydration and become increasingly evident towards the end of a competitive match (Mohr et al., 2003; Silva et al., 2013).

Previous research has shown that inadequate recovery time can result in reduced performance during subsequent matches in collegiate soccer players (McCormack et al., 2015; Wells et al., 2015). McCormack et al. (2015) reported that 42 hours between matches did not allow for sufficient recovery between matches. Wells et al. (2015) observed significant declines in distance covered per minute under the demand of additional playing time during postseason play compared to regular season play, despite significantly increased absolute distance covered and distance covered at high speed. Others have reported that sprint performance declines steadily across a season, with slowest sprint time's occurring towards the end of a regular season (Kraemer et al., 2004; Mara, Thompson, Pumpa, & Ball, 2015). These reports indicate a potential for the development of non-functional overreaching or overtraining during the course of a season. Indeed, reports of overtraining are frequent in soccer players, especially at higher levels of competition (Matos, Winsley, & Williams, 2011). Consequently, monitoring athletes over time as well as during individual games may allow coaches to address potential perturbations in performance and make adjustments accordingly. This information may also allow for more

informed decisions regarding substitutions, starting lineups and training and nutritional strategies to optimize performance of players.

Measurement of in game performance

Heart rate measures have previously been used to quantify physiological stress of soccer specific activities. Ali & Farrally (1991) previously examined differences in HR responses of soccer players by playing position. They observed significantly higher heart rates in attackers and midfielders compared to defenders at all levels of competitive play. Aslan et al. (2012) examined changes in heart rate responses and ratings of perceived exertion in soccer players over the course of a competitive game. They demonstrated significant decreases in the average heart rate of players during the second half of play, with the lowest average heart rates occurring in the final 15 minutes of play. Interestingly, the lower average heart rates were associated with higher ratings of perceived exertion. Randers, Andersen, Rasmussen & Krustrup (2014) evaluated differences in heart rate responses and running performance of soccer players during 20-minute soccer matches using different team sizes. Heart rate responses were similar during 8v8 matches compared to 11v11, despite a significantly lower total distance covered and total distance covered within each speed zone during the 8v8 match. More recent reports suggest that over 70% of playing time in friendly matches is spent at heart rates between 81-94% of heart rate max, with an average of 84% (Mallo et al., 2015). Notwithstanding, there is currently a paucity of literature examining heart rate telemetry responses to quantify physiological stress over the course of a competitive season.

Recent technological advances have provided new ways to evaluate performance during competition. Time-motion video analysis has allowed performance variables such as total distance covered to be evaluated by trained investigators from multiple angles. Mohr et al.

(2003) utilized video analysis across two consecutive competitive seasons to evaluate differences between playing position as well as differences in skill level between elite level and moderate level professional players. Their results indicate that distance covered during high intensity running and sprinting is significantly greater for top class players compared to lower level players, which may explain differences in performance. Nevertheless, while this technology may be accurate in a variety of circumstances, data analysis is relatively time consuming compared to newer methods of quantification, and is not always practical due to stadium limitations, which prevent teams from being able to obtain data from matches not played at their home stadium. This limitation has been circumvented with the advent of wearable Global Positioning System (GPS) technology.

Wearable GPS technology has recently been utilized to evaluate changes in performance over time in various sports (Jennings, Cormack, Coutts, & Aughey, 2012; Wells et al., 2015). Jennings et al. (2012) evaluated differences in performance of elite male field hockey players over the course of six matches spanning nine consecutive days. They observed significant decreases in total distance and high-speed running distance among midfielders and strikers during later matches compared to the first match of the tournament, although the running performance of defenders was not significantly different between matches. Movement patterns and the intermittent nature of field hockey appear to be similar to that of soccer. Nevertheless, each half of an international match is only 35 minutes in duration compared to 45-minute halves in collegiate and international soccer. Further, field hockey rules allow for unlimited substitutions. It is therefore possible that reductions in performance were attenuated due to substitution patterns and reduced stress during each game. As such, while these results may

indicate reductions in performance during periods of intense training and competition, applicability to collegiate soccer may be limited.

Research evaluating changes in soccer performance across a competitive season have produced contrasting results. Mohr and colleagues (2003) observed significant increases in both total distance covered and the amount of HIR performed at the end of two consecutive seasons among 10 top class Italian players. Rampinini et al. (2007) observed comparable results, with top class players covering significantly greater total distance, high intensity running and very high intensity running distance at the end of the competitive season compared with the beginning. Similarly, Silva et al. (2013) observed significant increases in both medium speed and sprint distance during the final quarter of a season compared to the third quarter and first three quarters of the competitive season, respectively. In contrast, Wells et al. (2015) observed significant decreases in exertion index, player load, energy cost and distance covered relative to minutes played during post-season play compared to regular-season play in elite collegiate women soccer players. While differences in results between studies may be due to contextual factors of each study, such as gender, and timing of assessment in relation to the competitive schedule (e.g. regular season vs. postseason), discrepancies may also be due to different definitions for velocity thresholds used in each study. Silva and colleagues utilized eight velocity thresholds including backwards running, with no velocity threshold dedicated to standing/transient motion. Medium speed running thresholds were defined as velocities registered between 4.17-5.0 $m·s^{-1}$, and sprinting velocity as 8.33 $m·s^{-1}$ in male soccer. Values for medium speed running in Silva's research fell mostly under the definition of high-speed running (i.e. 4.43- 6.08 $m·s^{-1}$) according to research by Wells et al. (2015). The thresholds used by Wells et al were based on previous work using female soccer players (Mohr, Krustrup, Andersson, Kirkendal, & Bangsbo, 2008).

However, velocity thresholds used for evaluation of running performance in female soccer players have varied widely. Multiple studies have either omitted standing/transient motion thresholds or used varying definitions, while sprinting velocity thresholds have been defined as low as 5.5+ m·s^{-1} and as high as 8.33+ m·s^{-1}, (Dwyer & Gabbett, 2012; Mohr et al., 2008). These findings seem to highlight the need for standardized velocity thresholds in both genders that may be used to allow for comparison between studies. In light of this, Dwyer & Gabbett (2012) recently established standardized velocity thresholds for elite male soccer players. Following an evaluation of the movement patterns over the course of 5 competitive matches, the authors recommended velocity thresholds for elite men be set at 0-0.1 m·s^{-1} (0.0-0.71 km·hr^{-1}) for standing, 0.2-2.0 m·s^{-1} (0.72-7.2 km·hr^{-1}) for walking, 2.1-3.7 m·s^{-1} (7.21-13.32 km·hr^{-1}) for jogging, 3.8-6.0 m·s^{-1} (13.33-21.6 km·hr^{-1}) for running, and $\geq$ 6.1 m·s^{-1} (>21.61 km·hr^{-1}) for sprinting.

GPS technology has enabled the quantification of running performance, regardless of match location. Advantages over previous technology (e.g. video capture) include real-time data processing, the ability to monitor a large number of athletes simultaneously, and greater objectivity in dependent measures of performance (Randers et al., 2010). However, one limitation of currently available GPS systems is the lack of integrated mechanical and physiological data to adequately characterize the stress placed on athletes during a match. Heart rate telemetry may be used to quantify energy expenditure and cardiovascular strain during exercise. However, it is important that this data be viewed in conjunction with performance data obtained via visual capture systems or wearable GPS systems to accurately quantify the physical demands of competition (Drust, Atkinson, & Reilly, 2007). Previously, the simultaneous collection of HR and GPS data meant that two separate systems with independent software's had

to be utilized. This configuration requires the execution of two independent analyses, making data collection less cost effective and time efficient (Randers et al., 2014). Further, these data often cannot be integrated or viewed in conjunction with each other. The use of independent GPS harnesses and heart rate monitors can also create issues regarding athlete comfort (Wells et al. 2015: unpublished observations), making their incorporation impractical during competitive play. Consequently, the development of integrated systems to simultaneously record heart rate and GPS data that are comfortable for athletes to wear may improve efficiency of data collection and allow conclusions to be drawn that may not be possible with GPS alone.

Newly available products such as the Bioharness 3^{TM} allow for an integrated approach to in game analysis. The Bioharness 3^{TM} (Zephyr Technology, MD, USA), is a wearable harness that provides both physiological data (e.g. heart rate, breathing rate, skin temperature) and spatial data obtained from GPS units in one harness. The harness includes electrode sensors embedded within a chest strap capable of detecting heart rate at a sampling rate of 250 Hz, and a GPS unit (Qstarz 818XT, Taipei, Taiwan) housed on the upper thoracic spine capable of sampling at 10Hz and logging at 1Hz. The GPS unit transmits data via Bluetooth to a module positioned on participant's left side, located along the midaxillary line, paralleling the xyphoid process of the sternum. During collection periods, the modules transmit data to a nearby computer with appropriate collection software via a wireless personal area network configured according to the 802.15.4 protocol.

The Bioharness system has been shown to have high levels of validity and reliability for measures of heart rate during an incremental treadmill running protocol (Johnstone, Ford, Hughes, Watson, & Garrett, 2012a; Johnstone, Ford, Hughes, Watson, & Garrett, 2012b). Additionally, 1Hz GPS has previously shown to be both valid and reliable for quantifying

distance covered during soccer specific activities (Portas, Harley, Barnes, & Rush, 2010). Therefore, use of the Bioharness™ is considered valid and reliable for measures of distance and heart rate during soccer specific activities. Notwithstanding, there is currently a paucity of research available using the Bioharness3™ physiological harness to evaluate measures of physical performance and physiological stress during competitive play in soccer players.

Contextual factors influencing performance

Previous research has indicated that contextual factors such as strength of opponent, match location, and/or match status may account for differences in running performance (Lago et al., 2010). Consequently, it is important that these factors be accounted for when recording in-match data over multiple time points. RPI is a measure of relative strength of NCAA teams that accounts for strength of opponent based upon strength of schedule as well as win-loss record of a team. Strength of schedule accounts for 50% of the RPI calculation, while wins and losses accounts for 25% of the RPI calculation. The index also takes into account the winning percentage of the opponents' opponents, which accounts for the final 25% of the RPI ranking. RPI has been used previously to account for differences in strength of opponent when evaluating in game running performance using GPS (Wells et al., 2015). Lago et al. (2010) compared quality of opposition (i.e. difference in final ranking between compared to opponents) in order to determine strength of opponent, and reported that total distance covered was significantly higher when playing tougher opponents. However, since final ranking may be influenced by win-loss record to a greater extent than RPI, it may not allow for truly accurate comparison of strength of teams across the entire season.

Evaluation of stress

Stress can be defined as the internal or external stimuli experienced by individuals during day-to-day life, training and/or competition. Soccer players are frequently reported to cover less total distance during the 2nd half of a match compared to the first half (Bradley & Noakes, 2013), with significantly less total distance being covered during the final 15 minutes of a match than in the first 15 minutes (Mohr et al., 2003). Additionally, an 8% reduction in high-intensity running has been observed following an initial 5-minute period of high intensity running, suggesting that participation in a soccer match is associated with a significant physical stress. If the day-to-day stress placed on athletes is too great or recovery from stress is inadequate, overtraining may manifest over time, resulting in reduced physical performance, faster onset and accumulation of fatigue during exercise, and increased subjective reports of stress (Urhausen, Gabriel, & Kindermann, 1995). If the training of athletes does not account for these performance decrements due to increased training stress, deficits may accrue over time. Consequently, in addition to quantification of the acute effects of physical stress on running performance, indicators of stress should be monitored over time to evaluate whether accumulated stress results in reduced running performance.

A number of techniques have previously been used to evaluate the effects of accumulated stress on markers of performance. Kraemer et al. (2004) assessed changes in hormonal concentrations of testosterone and cortisol in conjunction with sport-specific measures of performance in collegiate soccer players across a 19 game season. Serum cortisol concentrations were significantly elevated in starters at week 8 of the competitive period. In addition, significant reductions in sprint speed, vertical jump height and peak isokinetic torque (1.05 rad·sec^{-1}) relative to baseline were also observed during the course of the season (Kraemer et al., 2004).

However, neither testosterone, cortisol, nor the T/C ratio correlated significantly with performance decrements at any time point. These results indicate that although serum cortisol concentrations are changed in response to increased stress, this measure may not be sensitive enough to predict declines in performance in soccer players across a season. In a similar study, Michailidis (2014) monitored seasonal changes in serum testosterone and cortisol concentrations in professional soccer players. They observed significant changes in testosterone, cortisol and the T/C ratio over time. Testosterone was significantly elevated at the end of the re-building phase, and was significantly reduced to below pre re-building phase concentrations at the end of the competitive phase. Cortisol was significantly lower at the end of the re-building phase, and significantly higher at the midpoint of the competitive season. The T/C ratio increased from pre re-building to post re-building, and was reduced compared to baseline at midseason and end of season measurements. Coelho et al. (2015) also monitored changes in serum concentrations of testosterone and cortisol across a professional soccer season, in addition to concentrations of creatine kinase, muscle alpha-actin, and interleukin-6. Measures were taken prior to the start of preseason, at the end of preseason and at the end of the competitive season. They observed significant declines in testosterone at the end of the preseason and regular season compared to baseline measures. Cortisol was elevated at the end of the competitive season compared to the end of preseason, while the T/C ratio was elevated at the end of preseason, and decreased at the end of the regular season compared to the start of the preseason. Creatine kinase measures were significantly elevated at end of preseason and competitive season compared to beginning of preseason. Alpha-actin concentrations were significantly increased at the end of the regular season compared to the beginning of preseason. Although both of these studies utilized serum measures of stress and recovery across a season, changes in performance were not measured in

either study. Nevertheless, these results suggest that hormonal markers of stress may be elevated in high-level soccer players during the later parts of a season. Notwithstanding, the assessment of serum markers include invasive procedures, may be relatively expensive and time consuming, and may not directly relate to subsequent changes in performance.

Heart rate variability (HRV) is a parameter that measures the time and frequency of heart rate in order to provide an indirect measure of the interplay between systems responsible for cardiovascular control (i.e. sympathetic/parasympathetic nervous stimulation, renin-angiotensin system; (Akselrod et al., 1981). During the early stages of overtraining, it is hypothesized that the sympathetic nervous system is primarily responsible for control of resting heart rate, while later stages of overtraining result in inhibition of the sympathetic nervous system and increased parasympathetic stimulation (Kuipers, 1998). Quantification of sympathetic and parasympathetic control of heart rate in this manner allows for assessment of stress and recovery in athletes. Buchheit et al. (2012) observed a moderate negative correlation between post-exercise vagal-related HRV (sum of squares of differences between adjacent normal R-R intervals) at baseline, and changes in repeated sprint performance in adolescent soccer players. In contrast, research using nocturnal HRV measures have indicated no difference in autonomic control of heart rate between overtrained and control athletes (Hynynen, Uusitalo, Konttinen, & Rusko, 2006). HRV measures obtained during sleep may allow for a more accurate assessment of HRV, since this dramatically reduces the influence of external stimuli, which could interfere with autonomic control of heart rate. However, the athletes used in this study were clinically diagnosed with overtraining syndrome and were required to have experienced performance reductions for a minimum of three weeks. Further, this study did not provide a true baseline assessment of HRV prior to development of overtraining, making comparisons between groups difficult. In a similar

study, Pichot et al. (2000) reported that during a 3-week intensive training phase, middle distance runners experienced a marked reduction in parasympathetic stimulation with concomitant increases in sympathetic stimulation, indicating that periods of increased training stress may lead to disruptions in normal autonomic control. Nevertheless, HRV measures are affected by factors such as changes in body position, posture and hydration status, which may limit the practicality of monitoring training stress using HRV during waking hours (Castro-Sepulveda et al., 2015; Kim & Euler, 1997).

Session Rating of Perceived Exertion (RPE) has previously been used to quantify an athlete's perception of training stress, as well as the time spent performing an activity. When evaluating the relationship between session RPE and resting HRV differences across a week Sartor et al. (2013) found weak, but statistically significant negative correlations. Previous research has also indicated that elite adolescent soccer players experience greater weekly training loads compared with younger players (Wrigley, Drust, Stratton, Scott, & Gregson, 2012). As athlete's mature, training demands typically increase (e.g. introduction of resistance training). Rules for substitution also become more restrictive during match play, while training and competition demands increase. Session RPE may be preferable to other methods due to time constraints of athletes, particularly during periods of intense training. RPE is also minimally invasive and accounts for the athlete's subjective feelings of training stress.

One limitation of methods such as session RPE for evaluating training stress are that they only account for stress placed upon athletes during training, and do not evaluate stressors from external sources such as work, classes or interpersonal relationships. In collegiate athletics, it is particularly important that changes in performance be viewed in the context of all potential sources of stress placed on the athlete. Psychometric evaluation using the Profile of Mood States

questionnaire has been used previously in both team and individual sports to evaluate mood states of athletes and monitor for signs of nonfunctional overreaching. Originally developed by McNaire (1971), the POMS is a 65-item questionnaire that assesses mood states of tension, depression, anger, vigor, fatigue, and confusion. Previous research has indicated that professional soccer players experience greater mood disturbances over the course of a season compared to lower level or recreational players, particularly in the subscales of tension, depression and confusion (Lovell et al., 2010). Similar changes in the iceberg profile were observed in university soccer players, with vigor reductions reported over the course of a competitive season. However, POMS scores are reported to be acutely sensitive to match outcome (winning vs. losing), bringing into question the validity of the POMS in determining true changes in mood state among athletes (Hassmen & Blomstrand, 1995). Additionally, this measure only contains one subscale associated with a positive mood state (i.e. vigor), which may not allow for more detailed accounting of individual sources of stress placed on an athlete. Further, responses are assessed using a 5 point Likert scale instead of the traditional 6 point scale, which previous research has shown to not produce normally distributed data resulting in higher levels of skewness and kurtosis when compared to 6 point and 11 point scales (Leung, 2011). Therefore, whenever appropriate, larger scales should be used in place of smaller scales due to increased sensitivity as well as improved distribution of data.

Recovery Stress Questionnaire-52 Sport (RESTQ 52) for evaluation of stress-recovery state

The Recovery Stress Questionnaire Sport (RESTQ), originally developed by Kallus (1995), is a 76-item survey that asks individuals to answer questions on a 0-6 Likert scale according to how they have felt over the past three days and nights. A shorter, 52 item version was later developed, known as the RESTQ 52 Sport. Responses are summed according to

administration instructions, generating ten stress subscales (e.g. disturbed breaks, burnout/emotional exhaustion, fatigue, etc.) and nine recovery subscales (e.g. success, general well-being, self-efficacy, etc.). These subscales are then summed in order to produce four scales, including general stress, general recovery, sport specific stress and sport specific recovery. Global stress and global recovery measures are subsequently obtained from the summation of stress scales and recovery scales, respectively. Global stress can then be subtracted from global recovery in order to give the Total Recovery Stress Score. Previous research has demonstrated acceptable validity and reliability of the RESTQ Sport (Kellman & Kallus, 2001; Martinent, 2014).

The RESTQ Sport has been used previously to quantify the stress-recovery state in a number of athletic populations (Kellman & Gunther, 2000; Coutts et al., 2007; Nunes et al., 2014; Auersperger et al., 2014; Meister et al., 2013). Kellman & Gunther (2000) observed a significant reduction in recovery scales following an increase in high altitude training volume in Olympic rowers. Coutts, Wallace & Slattery (2007) observed a significant decrease in the recovery stress balance of competitive triathletes subjected to a 4-week of intensive training in comparison to triathletes subjected to a normal training stimulus. Interestingly, these changes occurred without concomitant changes in serum biomarkers of training stress. More recently, Nunes et al. (2014) observed significant decreases in the stress-recovery state of elite female basketball players during periods of increased training load over the course of a 12 week periodized resistance-training program. Similarly, Auersperger et al. (2014) observed significant declines in sport specific recovery subscales during periods of increased loading in long-distance runners. These changes also occurred without concomitant changes in serum biomarkers of training stress. In contrast to these studies, Meister et al. (2013) observed no differences in stress

or recovery between soccer players experiencing high amounts of match exposure (i.e. greater than 270 minutes over three weeks) and those experiencing low amounts of match exposure (i.e. less than 270 minutes over three weeks). Notwithstanding, the majority of studies appear to indicate that RESTQ stress and recovery scales are robustly sensitive to changes in training volume and intensity. Accordingly, the RESTQ Sport appears to be a viable tool for monitoring recovery and stress of athletes across time. Nevertheless, there is currently a lack of literature examining how changes in running performance across a competitive collegiate soccer season relate to differences in the stress-recovery state. Therefore, the purpose of this study is to evaluate the relationship between changes in the stress-recovery state and running performance in collegiate male soccer players over the course of a regular competitive season.

Research Questions

Do collegiate soccer players experience declines in running performance across a competitive season?

Do changes in general stress relate to changes in running performance across a competitive soccer season?

Do changes in general recovery relate to changes in running performance across a competitive soccer season?

Do changes in sport specific stress relate to changes in running performance across a competitive soccer season?

Do changes in sport specific recovery relate to changes in running performance across a competitive soccer season?

Hypotheses

It is hypothesized that running performance will decline across a competitive season

It is hypothesized that a negative relationship exists between general stress subscales and running performance across a competitive season

It is hypothesized that a positive relationship exists between general recovery subscales and running performance across a competitive season

It is hypothesized that a negative relationship exists between sport specific stress subscales and running performance across a competitive season

It is hypothesized that a positive relationship exists between sport specific recovery subscales and running performance across a competitive season

Limitations

1 Hz GPS may underestimate complex movement patterns such as those completed during a soccer match

Investigators have no way of knowing if athletes answer surveys honestly

Small sample size limits ability of results to be generalized to a larger population

Delimitations

Sample of male collegiate soccer players, which are not often studied

Use of Bioharness^{TM} for performance measurements, which allow for GPS and heart rate collection simultaneously

Assumptions

It is assumed that participants will answer surveys honestly

It is assumed that wearing the Bioharness^{TM} will not alter performance of players

It is assumed that participants are following a similar training program to minimize differences between participants regarding alternate sources of stress

Definitions

Soccer player: currently active player on Georgia Southern University men's soccer team

Running performance: total distance as well as distance covered engaging in high intensity running over the course of a match

CHAPTER 3: METHODOLOGY

Study Design

Running performance and game load (GLoad) were assessed in 15 NCAA Division 1 male soccer athletes in conjunction with measures of stress and recovery. Athletes were tracked over 12 competitive regular-season games. The season was divided into four competitive blocks [B1 ($n = 3$), B2 ($n = 3$), B3 ($n = 3$), and B4 ($n=3$)]. Absolute running distance, distance covered in each of six velocity categories, GLoad, general stress, general recovery, sport specific stress, sport specific recovery, global stress, global recovery, and the recovery-stress balance were assessed in all 12 games. Running performance and GLoad were also assessed relative to minutes played. Data was obtained as part of collaboration between the School of Health and Kinesiology and the men's soccer team for the purpose of providing feedback on player performance to coaches. A retrospective examination of the data was approved by the Georgia Southern University Institutional Review Board following completion of the competitive season. Each athlete provided written consent for use of de-identified data.

Participants

In order to be included in this study, participants had to be current active players on the Georgia Southern University men's soccer team playing an average of 45 minutes or more per game across the season. This is consistent with previous investigations (McCormack et al., 2015). Exclusion criteria included athletes missing data for more than one match, investigators not being able to determine authenticity of responses from surveys, or participants not providing consent for retrospective analysis of de-identified data. Of the original sample, 2 athletes were withheld from analysis for not providing consent, while 5 were withheld for not meeting the

inclusion criteria, yielding a final sample of eight players (179.39 ± 5.24 cm; 75.46 ± 5.98 kg; 20.37 ± 1.41 yrs) for analysis (range: 62.81-96.34 min; team average: 77.93 ± 18.13 min). The sample included defenders (n=3), midfielders (n=2) and attackers (n=3), and players completed an average of 87.03% of games over the season. The team finished the competitive season with a win-loss record of (6-8-1), and an end of season Rating Percentage Index (RPI) of 166. Prior to the first game of the season, body mass (±0.1 kg), and height (±0.1 cm) were measured using a calibrated scale (Life Measurements, Concord, CA, USA) and stadiometer (Detecto, Webb City, MO, USA) respectively.

Procedures

Prior to each game, participants were outfitted with a Zephyr bioharness (Model BH3, Zephyr Technology Corporation, Annapolis, MD, USA), and a 10Hz global positioning receiver/transmitter (BT-Q818XT, QStarz, Taipei, Taiwan). The bioharness and GPS unit are depicted in Figure 1. The bioharness is a wireless, ambulatory physiological monitoring device that consists of a chest strap and battery operated monitoring device (biomodule). The biomodule, which functions as a transmitter and data logger, attaches to a receptacle in the chest strap, and captures heart rate data through conductive fabric skin electrode sensors housed in the chest strap. The biomodule also houses a tri-axial accelerometer sampling at 100Hz, and integrates real time GPS data via Bluetooth. GPS data is sampled at 10Hz and logged at 1Hz. All data is transmitted via a low rate wireless personal area network structured on the 802.15.4 protocol. Signal amplifiers were used to extend the range of wireless transmission to 333 yards. Previous research has shown 1 Hz GPS to be valid and reliable for total distance in soccer specific movements. Zephyr heart rate sensors have been previously validated for use during exercise using a criterion three lead ECG (Johnstone et al., 2012a). In addition, the bioharness

has been recently shown to have strong reliability (Johnstone et al., 2012; Johnstone et al., 2012b).

Prior to the start of the season, GPS units and bio-modules were matched and coded, and the same units were used for each player for all competitive games. GPS units were powered on 15 minutes prior to the start of the game to achieve acquisition of satellite signals, which is consistent with previous research (Wells et al., 2015). Following the pre-game warm-up, synced GPS units and bio-modules were fitted into each athletes' harness. The GPS device was positioned over the upper-thoracic spine between the scapulae, and the bio-module along the midaxillary line on the left side of the body, underneath the jersey. Investigators ensured correct placement of GPS and bio-module prior to the start of each game. Players were tracked in real time using a laptop computer with Omnisense Live™ version 2.3 software and antenna. Data collection for each period was synchronized with the referee's whistle, and substitutions were recorded by investigators on the sidelines. Only data amassed during playing time was utilized during analysis. This was accomplished through the creation of sub-sessions for each athlete prior to the download of recorded data. The following parameters were downloaded from the GPS devices and bio-modules to Omnisense Analysis™ version 2.3 for analysis.

Time and Distance

Minutes played and distance covered were downloaded and exported for analysis. Distance covered was extracted as absolute distance covered (meters) per game and distance covered relative to minutes played. Movements on the field were divided into distinct velocity thresholds according to previously established guidelines for male soccer players (Dwyer & Gabbett, 2012). Velocity thresholds were defined as standing (0.0-0.1 m$\cdot$s^{-1}; 0.0-0.71 km$\cdot$h^{-1}), walking (0.2-2.0 m$\cdot$s^{-1}; 0.72-7.20 km$\cdot$h^{-1}), jogging (2.1-3.7 m$\cdot$s^{-1}; 7.21-13.32 km$\cdot$h^{-1}), low speed

running (3.8-4.9 $m \cdot s^{-1}$; 13.33-17.99 $km \cdot h^{-1}$), high speed running (5.0-6.0 $m \cdot s^{-1}$; 18.0-21.6 $km \cdot h^{-1}$) and sprinting (6.1+ $m \cdot s^{-1}$; 21.6+ $km \cdot h^{-1}$). Velocity thresholds were further categorized in terms of low intensity running (0.2-4.9 $m \cdot s^{-1}$;0.72-17.99 $km \cdot hr^{-1}$) and high intensity running ($\geq$5.0 $m \cdot s^{-1}$; $\geq$18.0 $km \cdot hr^{-1}$).

Game Load

GLoad was assessed using the training load parameter provided by the Zephyr Analysis software. Training load is a summation of the average of the physiological load and mechanical load parameters over the entire recording period. This allows for assessment of internal and external work performed by a player over a given recording period. Heart rate and accelerometry data was obtained during each game, from which physiological and mechanical intensity values were automatically calculated. Physiological and mechanical intensity values were then summed over the recording period to calculate physiological and mechanical load, respectively. Data was stored internally within the biomodule and downloaded after each game for analysis.

Physiological intensity was determined through assessment of heart rate data obtained from the bio-module housed in the chest strap. Physiological intensity is a measure that is assessed each second during collection, measured using a continuous scale from 0.0 to 10.0 in arbitrary units of intensity. This value is set up within the Omnisense Live software to register increasing intensity as participants obtain higher %HR_{max} values. All heart rates detected below 50%HR_{max} are reported as 0.0, while all heart rates detected at or above 100%HR_{max} are reported as 10.0. All intensity values are scaled to produce corresponding intensity values on a 0.0 to 10.0 scale (e.g. 60% HR_{max} would correspond to 2.0, 85% would correspond to 7.0, etc.). Physiological intensity values were summed over the recording period to produce the

physiological load variable (i.e. intensity measures of 4.2 and 5.3, measured over two seconds, would yield a corresponding load of 9.5).

Mechanical intensity was determined through assessment of accelerometry measures obtained from tri-axial accelerometers located within the bio-module. Mechanical intensity was measured each second and reported in arbitrary units of intensity from 0.0 to 10.0, based on g-forces measured from accelerometers, where 0.0g was reported as 0.0 and 5.5g or greater was reported as 10.0. Mechanical load is a summative value of all mechanical intensity values in a given recording period.

Recovery and Stress assessment

Measures of recovery and stress were quantified using the REST-Q 52 Sport survey. This survey consists of 52 questions designed to evaluate participant's perceived levels of stress and recovery over the previous three days and nights. The REST-Q 52 Sport consists of 52 items Questions were answered on a seven point Likert-type scale ranging from 0-6, with 0 indicating never experiencing the feeling associated with a given question, and 6 indicating always experiencing the associated feeling. Two surveys were distributed during each competitive block, separated by a minimum of one week. Scores were summed according to the REST-Q administration manual to give measures of general stress (GS), general recovery (GR), sport specific stress (SSS), sport specific recovery (SSR), global stress (GS), global recovery (GR), and the recovery-stress balance (RSB). This survey has previously been used to quantify physical strain and overload in elite male soccer players, and has shown to high internal consistency (Cronbach's α=0.67-0.89) (Kellman, 2010; Meister et al., 2013).

Rating Percentage Index

RPI is a measure of relative strength of NCAA teams that accounts for strength of opponent based upon strength of schedule as well as win-loss record of a team. Strength of schedule accounts for 50% of the RPI calculation, while wins and losses accounts for 25% of the RPI calculation. The index also takes into account the winning percentage of the opponents' opponents, which accounts for the final 25% of the RPI ranking. The end of season RPI ranking for each opponent was utilized to assess changes in the strength of opponent over the course of the season. Strength of schedule accounts for 50% of the RPI calculation, while win-loss record and opponent's win percentage each account for 25%. RPI has previously been reported as a measure of strength of opponent in collegiate women's soccer (Wells et al., 2015).

Statistical Analyses

The regular season was divided into four competitive blocks: B1 (n=3), B2 (n=3), B3 (n=3) and B4 (n=3). Statistical analysis of performance and REST-Q data was accomplished using a 4-way repeated measures analysis of variance (ANOVA) across the competitive regular-season. In the event of a significant F ratio, least significant difference (LSD) post hoc tests were used for pairwise comparisons. Changes in dependent variables across time were further analyzed using Cohen's *d* for effect sizes and 95% confidence intervals (CIs). Interpretations of effect size were evaluated in accordance with (Thalheimer & Cook, 2002) at the following levels: negligible effect (≥−0.15 and <0.15), small effect (≥0.15 and <0.40), medium/moderate effect (≥0.40 and <0.75), large effect (≥0.75 and <1.10), very large effect (≥1.10 and <1.45), and huge effect ≥1.45). Time effects were further analyzed using partial eta squared (η^2_p). Interpretations of η^2_p were evaluated in accordance with Cohen (1988) at the following levels:

small effect (0.01-0.058), medium effect (0.059-0.137) and large effect (>0.138). RPI was

analyzed using the Kruskall-Wallis H test for differences in rank. Correlations between

performance measures and REST-Q results were assessed using Pearson moment product

correlation coefficients. Interpretations of correlation coefficients were evaluated in accordance

with Cohen (1988) at the following levels: small correlation (0.1-0.3), moderate correlation (0.3-

0.5) and strong correlation (0.5-1.0). A criterion α-level of $p \leq 0.05$ was used to determine

statistical significance. Data are presented as means $\pm$ 95% CIs unless otherwise indicated. Data

analysis was accomplished using IBM SPSS Version 21 (IBM Corp., Armonk, NY, USA).

CHAPTER 4: RESULTS

Opponent Ranking

No significant differences were observed between blocks for RPI (p=0.557), indicating that strength of opponent was similar across the season.

Minutes Played

Average playing time during each competitive block is presented in Table 1. No significant differences were observed for playing time between blocks (p=0.203), indicating that playing time was similar across the season.

Running Performance

Changes in absolute distance covered and absolute distance covered within each velocity threshold are presented in Table 1. A significant time effect was also observed for absolute jogging distance across the season (F=6.0; p=0.005; η^2_p= 0.50). Pairwise comparisons indicated that absolute jogging distance was significantly greater during B4 compared to B1 (d=1.25; p= 0.009; 95% CIs= +327.60 m to +1486.37 m), B2 (d=1.18; p=0.050; 95% CIs= +0.84 m to +1447.58 m), and B3 (d= 0.62; p=0.046; 95% CIs= +9.74 m to +860.07 m). Additionally, there was a trend towards an increase in absolute jogging distance was observed during B3 compared to B1 (d= 0.63; p=0.058; 95% CIs= +22.21 m to +922.37 m). A significant time effect was observed for absolute low speed running distance across the season (F= 6.4; p=0.017; η^2_p = 0.52). Pairwise comparisons revealed that absolute low speed running was significantly greater during B4 compared to B1 (d= 1.27; p=0.014; 95% CIs= +111.56 m to +670.89 m), B2 (d= 1.18; p= 0.012; 95% CIs= +112.78 m to +612.19 m), and B3 (d= 0.64; p<0.001; 95% CIs= +162.92 m

to +244.01 m). A significant time effect was also observed for LIR across the season (F=3.6; p=0.033; η^2_p= 0.38). Pairwise comparisons revealed that LIR was significantly greater during B4 compared to B1 (d=0.97; p=0.034; 95% CIs= +158.64 m to +2826.30 m). Additionally, there was a trend towards an increase in LIR during B3 compared to B1 (d=0.61; p=0.098; 95% CIs= -233.83 m to +2109.86 m) and B4 compared to B2 (d=1.00; p=0.099; 95% CIs= -339.52 m to +2983.44 m). No significant time effects were observed for absolute distance (p= 0.063), however, pairwise comparisons indicate total distance was significantly increased during B4 (d=0.93; p=0.027; 95% CIs= +245.13 m to +2831.78 m) compared to B1. No significant time effects were reported for distance covered walking (p = 0.439), high-speed running (p =0.200), sprinting (p= 0.654), or HIR (p= 0.271).

When distance was assessed relative to playing time, significant time effects were observed for jogging (F=6.48, p=0.004, η^2_p =0.52). Pairwise comparisons indicated that jogging distance was significantly greater during B4 compared to B1 (d=2.42; p=0.001; 95% CIs= +5.37 m·min^{-1} to +11.69 m·min^{-1}) and B3 (d = 2.02; p=0.001; 95% CI = +5.11 to +11.50 m). No significant differences were observed between blocks for total distance (p=0.137), walking (p=0.481), low speed running (p=0.080), LIR (p=0.187), high-speed running (p=0.073), sprinting (p=0.979), or HIR (p=0.359) relative to minutes played.

Game Load

Changes in measures GLoad are reported in Table 1. No significant differences were observed between blocks for absolute GLoad (p=0.538). Further, when GLoad was expressed to minutes played, no significant differences were observed between blocks (p=0.340).

TABLE 1. ABSOLUTE DISTANCE AND DISTANCE RELATIVE TO MINUTES PLAYED ACROSS BLOCKS OF COMPETITIVE SEASON.

Variable	B1	B2	B3	B4
Playing time (min)	78.0 ± 21.5	76.9 ± 11.0	90.3 ± 13.4	85.5 ± 14.6
Absolute				
GLoad	365.9 ± 103.5	371.6 ± 65.7	409.8 ± 67.4	375.3 ± 101.1
Total distance	8261.3 ± 1957.7	8492.3 ± 1257.7	9392.5 ± 1428.7	9904.5 ± 1490.3*
Walk	3029.4 ± 771.9	3042.7 ± 541.3	3419.2 ± 542.9	3313.6 ± 647.6
Jog	3082.3 ± 819.7	3219.7 ± 548.8	3591.5 ± 726.7	4050.5 ± 695.5**
Low-speed running	1351.1 ± 330.6	1326.7 ± 339.6	1536.3 ± 321.6	1716.3 ± 314.1**
High-speed running	517.3 ± 115.2	522.0 ± 127.4	535.8 ± 92.3	596.8 ± 100.4
Sprint	272.8 ± 113.7	280.3 ± 118.5	316.2 ± 90.8	298.1 ± 134.0
LIR	7462.7 ± 1796.7	7589.0 ± 1244.0	8547.0 ± 1416.7	9080.4 ± 1410.8*
HIR	790.1 ± 211.6	752.4 ± 176.7	820.1 ± 196.8	752.4 ± 255.1
Relative to minutes played				
GLoad	4.7 ± 0.4	4.8 ± 0.6	4.5 ± 0.3	4.4 ± 1.0
Total distance	107.4 ± 9.5	113.6 ± 18.5	104.7 ± 5.9	117.0 ± 8.4
Walk	39.1 ± 2.3	40.5 ± 6.6	37.8 ± 1.9	38.4 ± 2.6
Jog	39.8 ± 3.2	43.3 ± 9.1	39.9 ± 4.1	48.0 ± 4.1*,$
Low-speed running	17.81 ± 4.25	17.95 ± 4.87	17.44 ± 3.47	20.70 ± 4.71
High-speed running	6.92 ± 1.95	6.99 ± 1.68	6.12 ± 1.44	7.31 ± 1.64
Sprint	3.71 ± 1.46	3.61 ± 1.37	3.69 ± 1.54	3.69 ± 1.66
LIR	96.72 ± 7.38	101.81 ± 18.84	95.14 ± 6.24	107.06 ± 6.49
HIR	10.62 ± 3.19	10.59 ± 2.78	9.81 ± 2.81	11.00 ± 2.75

*$p<0.05$ compared to B1. **$p<0.05$ compared to all other time points. $$p<0.05$ compared to B3.
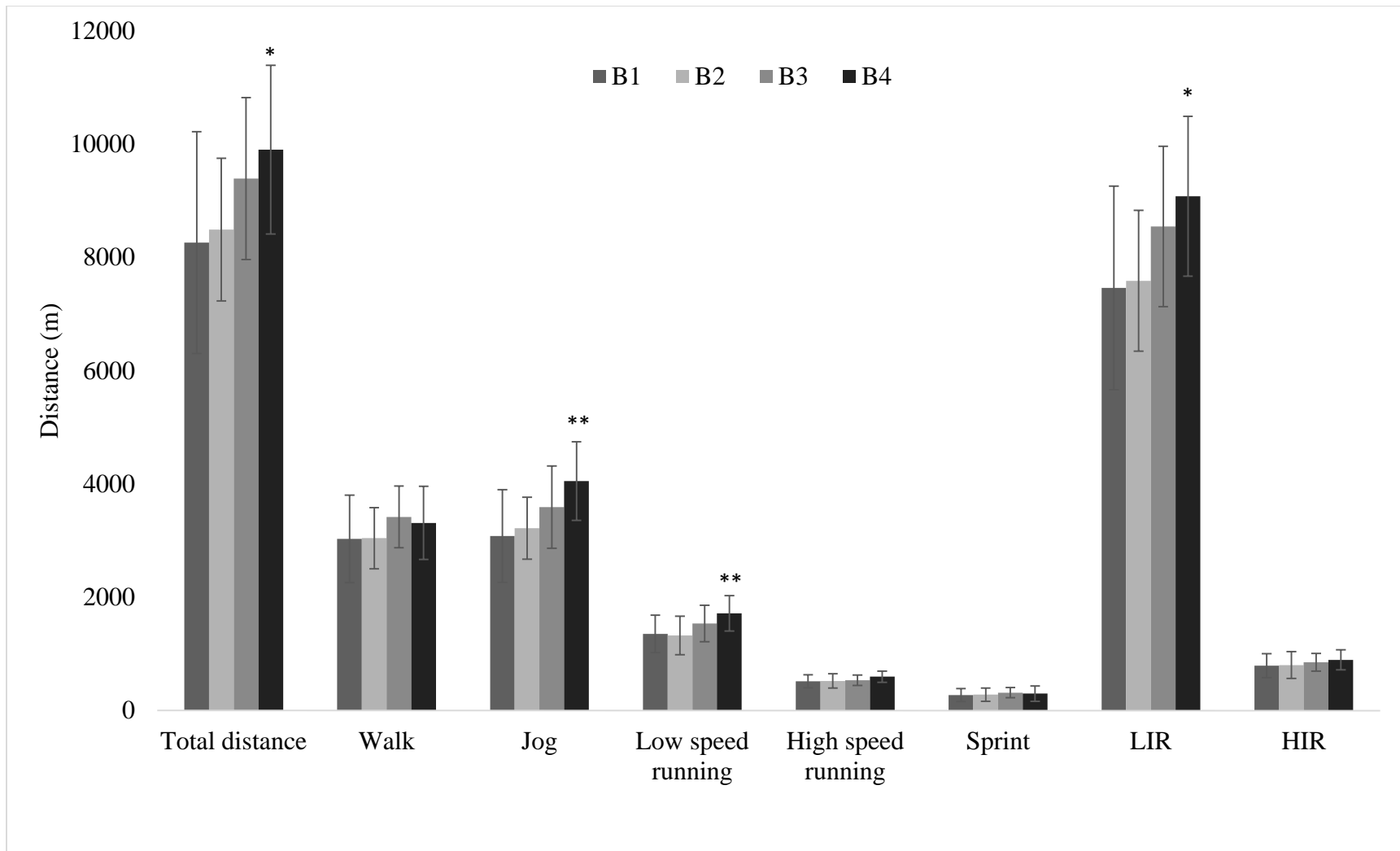
FIGURE 1. CHANGES IN ABSOLUTE RUNNING PERFORMANCE BETWEEN TRAINING BLOCKS. * P<0.05 DIFFERENCE FROM B1. ** P<0.05 DIFFERENCE FROM ALL OTHER TIME POINTS.
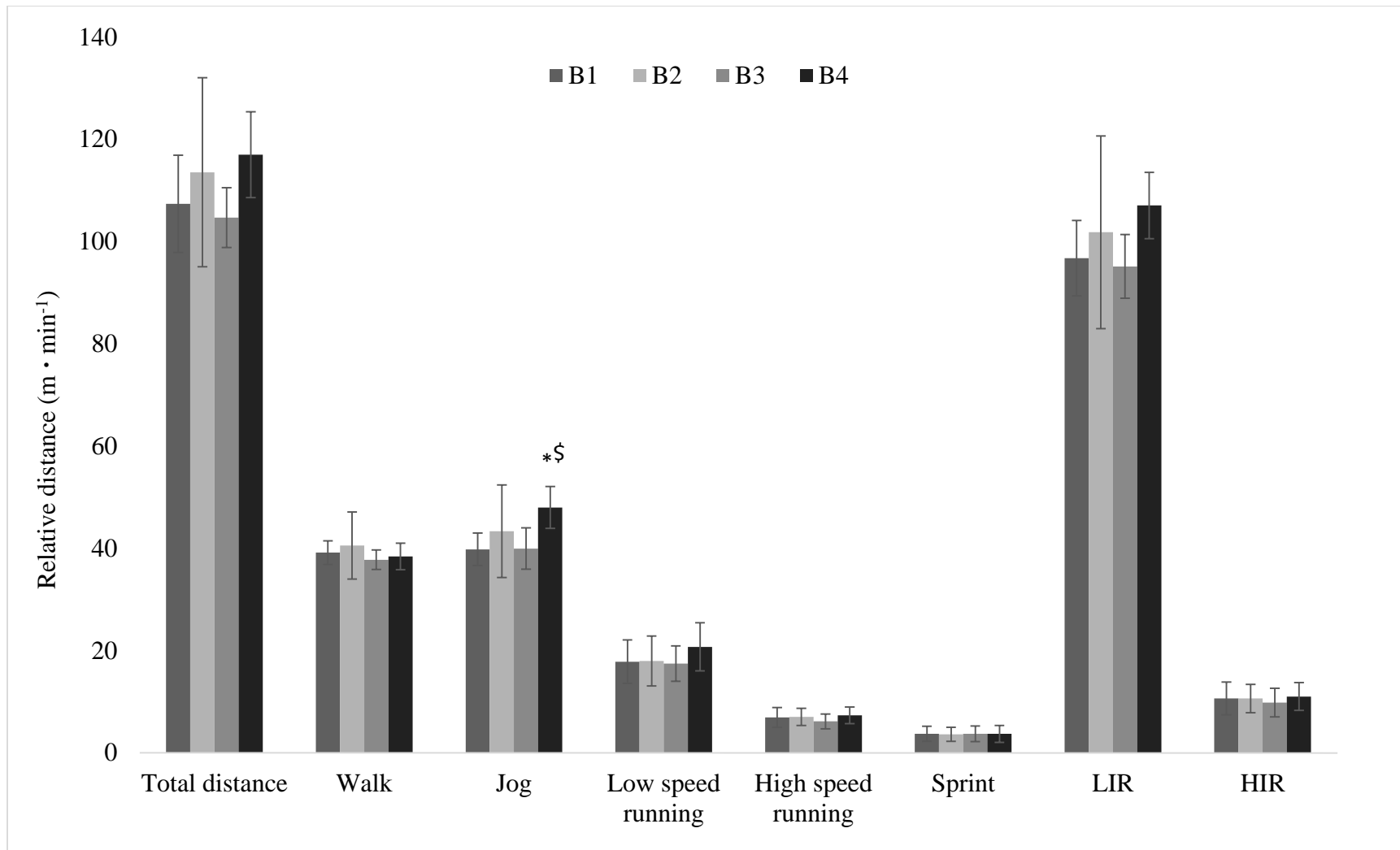
FIGURE 2. CHANGES IN RUNNING PERFORMANCE RELATIVE TO MINUTES PLAYED BETWEEN TRAINING BLOCKS. * P<0.05 DIFFERENCE FROM B1. $ P<0.05 DIFFERENCE FROM B3.

Recovery-stress state

Changes in measures of the stress-recovery state across time are reported in Table 2. A significant time effect was observed for sport specific recovery across the season (F= 3.24, p=0.046, η^2_p = 0.351). Pairwise comparisons indicated that SSR decreased significantly during B4 compared to B1 (d= 0.96; p=0.035; 95% CIs= -0.244 AU to -4.779 AU). No significant differences were observed for measures of general stress (p=0.502), general recovery (p=0.514), sport specific stress (p=0.953), global stress (p=0.671), global recovery (p=0.158) or the recovery-stress balance (p=0.352).

TABLE 2. CHANGES IN RESTQ SCALES ACROSS COMPETITIVE BLOCKS.

Variable	B1	B2	B3	B4
General stress	11.32 ± 4.49	11.91 ± 4.43	12.16 ± 4.33	11.53 ± 3.83
General recovery	16.82 ± 2.06	17.15 ± 2.89	16.34 ± 3.75	16.31 ± 2.64
Sport specific stress	5.54 ± 2.24	5.27 ± 2.23	5.26 ± 2.39	5.91 ± 2.58
Sport specific recovery	14.68 ± 3.20	13.49 ± 3.74	13.27 ± 3.29	12.21 ± 2.65*
Global stress	16.85 ± 5.70	17.17 ± 6.52	17.42 ± 6.65	17.44 ± 5.54
Global recovery	31.5 ± 5.11	30.65 ± 6.51	29.61 ± 6.96	28.52 ± 4.98
Recovery-stress balance	14.64 ± 10.04	13.48 ± 12.62	12.18 ± 13.10	11.08 ± 9.63

* p<0.05 difference from B1.
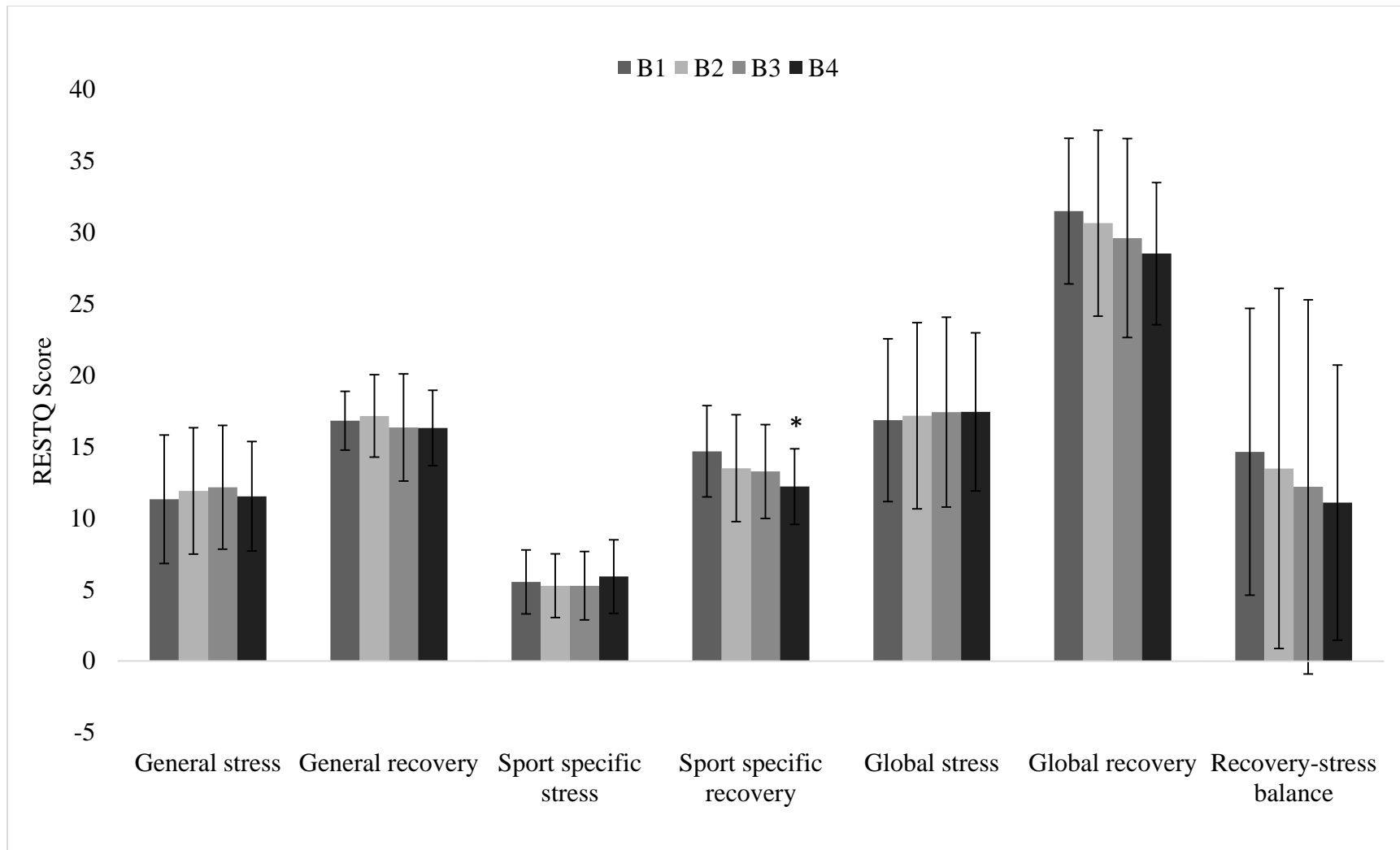
FIGURE 3. REST-Q CHANGES ACROSS BLOCKS OF COMPETITIVE SEASON. * P<0.05 DIFFERENCE FROM B1.

Correlations between RESTQ scales and running performance

Absolute running distance and RESTQ stress scales

Correlations between absolute running distance and RESTQ stress scales and are presented in Table 3. A significant positive correlations was observed between high-speed running and general stress (r=0.734; p=0.038) during B2. Additionally, a significant positive correlation was observed between HIR and general stress (r=0.723; p=0.043) during B2. Sprint distance was positively correlated with general stress (r=0.719; p=0.044), sport specific stress (r=0.737; p=0.037), and global stress (r=0.734; p=0.038) during B3. No other relationships between any measures of absolute running performance and RESTQ stress scales were observed during any competitive block.

Relative running distance and RESTQ stress scales

Correlations between relative running distance and RESTQ stress scales are presented in Table 4. Distance covered walking relative to minutes played was negatively correlated with general stress (r=-0.723; p=0.043), sport specific stress (r=-0.796; p=0.018), and global stress (r=-0.765; p=0.027) during B2. No other significant correlations were observed between measures of running performance relative to minutes played and RESTQ stress scales during any competitive block.

Absolute running distance and RESTQ recovery scales

Correlations between absolute running distance and RESTQ recovery scales are presented in Table 5. A significant positive correlation was observed between total distance and sport specific recovery (r=0.781; p=0.038) during B1. Absolute jogging distance and absolute LIR distance were positively correlated with sport specific recovery during B1 (r=0.788;

p=0.035 and r=0.784; p=0.037 respectively). Absolute sprint distance and absolute HIR distance were negatively correlated with measures of general recovery (r=-0.716; p=0.046 and r=-0.802; p=0.017 respectively), sport specific recovery (r=-0.801; p=0.017 and r=-0.801; p=0.017 respectively), global recovery (r=-0.763; p=0.028 and r=-0.810; p=0.015 respectively), and the recovery-stress balance (r=0.778; p=0.023 and r=-0.755, p=0.030 respectively) during B3. No other significant correlations were observed between absolute running performance and RESTQ recovery scales during any other competitive block. Further, no significant correlations were observed between changes in sport specific recovery from B1 to B4 and changes in absolute jogging distance (p=0.820), absolute low-speed running distance (p=0.829) and absolute LIR distance (p = 0.700) from B1 and B4.

Relative running distance and RESTQ recovery scales

Correlations between relative running distance and RESTQ recovery scales are presented in Table 6. Total distance was positively correlated with sport specific recovery (r=0.800; p=0.017) and global recovery (r=0.713; p=0.047) during B2. Walking distance was positively correlated with general recovery (r=0.804; p=0.016), sport specific recovery (r=0.804; p=0.001), global recovery (r=0.888; p=0.003) and the recovery-stress balance (r=0.853; p=0.007) during B2. Jogging distance was positively correlated with sport specific recovery during B2 (r=0.863; p=0.006) and B3 (r=0.749; p=0.032). Jogging distance was also positively correlated with global recovery (r=0.786; p=0.021) during B2. No other significant correlations were observed between running performance relative to minutes played and RESTQ recovery scales. Further, no significant correlations were observed between changes in sport specific recovery from B1 to B4 and jogging distance relative to minutes played from B1 to B4 (p=0.912).

Game Load and RESTQ stress scales

Correlations between GLoad and RESTQ stress scales are presented in Tables 3 and 4. No significant correlations were observed between absolute GLoad and RESTQ stress scales. When GLoad was expressed relative to minutes played, a significant negative correlation was observed between GLoad and SSS during B2 (r=-.751; p=0.032). No other significant correlations were observed between GLoad and RESTQ stress scales.

Game Load and RESTQ recovery scales

Correlations between GLoad and RESTQ recovery scales are presented in Tables 5 and 6. A significant positive correlation was observed between absolute GLoad and SSR during B1 (r=.807; p=0.028). When GLoad was expressed relative to minutes played, significant positive correlations were observed between GLoad and GR (r=.781; p= 0.022), SSR (r=.897; p= 0.002), GLR (r=.862; p= 0.006) and SRB (r=.738; p= 0.036). No other significant correlations were observed between GLoad relative to minutes played and RESTQ recovery scales.

TABLE 3. CORRELATION ANALYSIS OF ABSOLUTE DISTANCE VARIABLES AND RESTQ STRESS SCALES.

		B1		B2		B3		B4	
		r	p	r	p	r	p	r	p
GLoad	GS	-.169	0.718	-.516	0.712	-.599	0.150	.126	0.766
	SSS	-.302	0.510	-.418	0.302	-.410	0.314	.021	0.961
	GLS	-.252	0.558	-.250	0.551	-.512	0.195	.097	0.819
TD	GS	-.172	0.713	-.166	0.695	-.510	0.197	-.220	0.601
	SSS	-.216	0.643	-.457	0.256	-.361	0.379	-.303	0.466
	GLS	-.220	0.635	-.269	0.519	-.462	0.249	-.293	0.481
WALK	GS	-.082	0.861	-.447	0.266	-.456	0.256	.092	0.828
	SSS	-.305	0.506	-.513	0.194	-.293	0.481	-.055	0.897
	GLS	-.185	0.692	-.480	0.229	-.403	0.322	.038	0.928
JOG	GS	-.262	0.570	-.341	0.409	-.596	0.119	-.261	0.532
	SSS	-.263	0.569	-.634	0.091	-.480	0.229	-.331	0.424
	GLS	-.310	0.498	-.449	0.265	-.561	0.148	-.335	0.418
LSR	GS	-.397	0.378	-.056	0.895	-.434	0.283	-.480	0.228
	SSS	.123	0.794	-.343	0.405	-.400	0.327	-.398	0.329
	GLS	-.265	0.565	-.156	0.712	-.427	0.292	-.517	0.189
HSR	GS	.039	0.934	.734**	0.038	.323	0.435	.291	0.484
	SSS	.072	0.877	.556	0.153	.408	0.315	-.108	0.800
	GLS	.059	0.900	.690	0.058	.358	0.384	.151	0.721
SPRINT	GS	.681	0.092	.662	0.074	.719**	0.044	.078	0.854
	SSS	.104	0.825	.440	0.275	.737**	0.037	-.069	0.870
	GLS	.578	0.174	.600	0.115	.734**	0.038	.022	0.959
LIR	GS	-.228	0.623	-.360	0.381	-.579	0.132	-.193	0.646
	SSS	-.228	0.622	-.596	0.119	-.449	0.264	-.277	0.507
	GLS	-.270	0.559	-.449	0.264	-.539	0.168	-.263	0.530
HIR	GS	.387	0.391	.723**	0.043	.610	0.108	.225	0.593
	SSS	.095	0.839	.517	0.190	.671	0.068	-.114	0.789
	GLS	.343	0.452	.669	0.070	.640	0.088	.102	0.809

**= strong correlation

TABLE 4. CORRELATION ANALYSIS OF DISTANCE RELATIVE TO MINUTES PLAYED AND RESTQ STRESS SCALES.

		B1		B2		B3		B4	
		r	p	r	p	r	p	r	p
GLoad	GS	-.116	0.805	-.457	0.295	-.387	0.356	.150	0.723
	SSS	.125	0.769	-.751**	0.032	-.396	0.331	.046	0.914
	GLS	-.042	0.929	-.568	0.142	-.389	0.341	.125	0.768
TD	GS	-.011	0.981	-.408	0.316	-.265	0.526	-.547	0.161
	SSS	.450	0.310	-.655	0.078	-.319	0.441	-.450	0.264
	GLS	.168	0.719	-.502	0.205	-.288	0.490	-.588	0.126
WALK	GS	.394	0.381	-.723**	0.043	-.308	0.458	.349	0.397
	SSS	.242	0.601	-.796**	0.018	-.307	0.459	-.013	0.976
	GLS	.406	0.366	-.765**	0.027	-.311	0.453	.235	0.575
JOG	GS	-.353	0.437	-.475	0.235	-.503	0.204	-.574	0.137
	SSS	.422	0.345	-.704	0.051	-.504	0.203	-.475	0.235
	GLS	-.113	0.809	-.564	0.146	-.509	0.197	-.618	0.103
LSR	GS	-.272	0.556	-.216	0.608	-.137	0.746	-.435	0.281
	SSS	.435	0.330	-.457	0.255	-.239	0.569	-.237	0.573
	GLS	-.044	0.926	-.303	0.465	-.175	0.678	-.411	0.312
HSR	GS	.094	0.842	.557	0.152	.449	0.265	.057	0.893
	SSS	.246	0.595	.405	0.320	.386	0.345	-.059	0.890
	GLS	.170	0.715	.517	0.189	.432	0.286	.012	0.978
SPRINT	GS	.691	0.086	.646	0.084	.548	0.160	.009	0.982
	SSS	.245	0.597	.420	0.300	.457	0.255	-.003	0.995
	GLS	.641	0.121	.583	0.129	.521	0.185	.005	0.990
LIR	GS	.053	0.910	-.491	0.216	-.534	0.173	-.461	0.250
	SSS	.069	0.884	-.545	0.163	-.577	0.134	-.511	0.196
	GLS	.069	0.883	-.521	0.186	-.556	0.153	-.557	0.152
HIR	GS	.385	0.393	.355	0.388	.503	0.204	.211	0.616
	SSS	.153	0.744	.413	0.309	.416	0.305	-.110	0.796
	GLS	.364	0.422	.383	0.349	.478	0.231	.095	0.823

**= strong correlation

TABLE 5. CORRELATION ANALYSIS OF ABSOLUTE DISTANCE AND RESTQ RECOVERY SCALES.

		B1		B2		B3		B4	
		r	p	r	p	r	p	r	p
GLoad	GR	.600	0.154	.446	0.268	.429	0.289	-.026	0.951
	SSR	.807**	0.028	.425	0.294	.504	0.203	.415	0.307
	GLR	.747	0.054	.442	0.273	.469	0.241	.207	0.623
	RSB	.523	0.229	.357	0.385	.509	0.198	.051	0.904
TD	GR	.611	0.145	.398	0.329	.283	0.498	.201	0.634
	SSR	.781**	0.038	.473	0.236	.402	0.323	.208	0.622
	GLR	.735	0.06	.448	0.265	.342	0.407	.217	0.606
	RSB	.499	0.255	.370	0.366	.416	0.305	.281	0.501
WALK	GR	.495	0.258	.559	0.150	.175	0.679	-.092	0.829
	SSR	.745	0.055	.521	0.185	.210	0.617	.071	0.867
	GLR	.666	0.103	.547	0.161	.193	0.647	-.011	0.980
	RSB	.443	0.319	.530	0.176	.307	0.459	-.028	0.948
JOG	GR	.599	0.156	.597	0.118	.481	0.228	.330	0.424
	SSR	.788**	0.035	.688	0.059	.606	0.111	.324	0.434
	GLR	.735	0.06	.660	0.075	.545	0.163	.348	0.399
	RSB	.549	0.201	.573	0.138	.575	0.136	.372	0.364
LSR	GR	.688	0.088	.150	0.723	.268	0.520	.382	0.350
	SSR	.569	0.183	.327	0.429	.442	0.273	.016	0.970
	GLR	.633	0.127	.254	0.543	.353	0.391	.211	0.616
	RSB	.472	0.285	.212	0.614	.404	0.320	.407	0.317
HSR	GR	.594	0.16	-.689	0.059	-.649	0.082	-.357	0.385
	SSR	.502	0.251	-.570	0.140	-.565	0.144	-.356	0.386
	GLR	.553	0.198	-.633	0.092	-.616	0.104	-.379	0.354
	RSB	.248	0.592	-.683	0.062	-.509	0.197	-.283	0.497
SPRINT	GR	-.051	0.913	-.487	0.221	-.716**	0.046	-.201	0.634
	SSR	.071	0.88	-.435	0.282	-.801**	0.017	.041	0.923
	GLR	.023	0.96	-.466	0.245	-.763**	0.028	-.084	0.842
	RSB	-.316	0.489	-.551	0.157	-.778**	0.023	-.056	0.895
LIR	GR	.613	0.144	.547	0.160	.374	0.361	.206	0.625
	SSR	.784**	0.037	.620	0.101	.492	0.216	.196	0.642
	GLR	.738	0.058	.599	0.117	.434	0.283	.214	0.612
	RSB	.528	0.223	.541	0.166	.504	0.202	.261	0.532
HIR	GR	.296	0.519	-.612	0.107	-.802**	0.017	-.355	0.388
	SSR	.311	0.497	-.522	0.184	-.801**	0.017	-.171	0.685
	GLR	.314	0.493	-.571	0.139	-.810**	0.015	-.280	0.503
	RSB	-.035	0.940	-.640	0.087	-.755**	0.030	-.203	0.629

**= strong correlation

TABLE 6. CORRELATION ANALYSIS OF DISTANCE RELATIVE TO MINUTES PLAYED AND RESTQ RECOVERY SCALES.

		B1		B2		B3		B4	
		r	p	r	p	r	p	r	p
GLoad	GR	.542	0.209	.781**	0.022	.671	0.069	.021	0.960
	SSR	.317	0.489	.897**	0.002	.653	0.079	.518	0.189
	GLR	.417	0.353	.862**	0.006	.669	0.069	.287	0.491
	RSB	.236	0.611	.738**	0.036	.553	0.155	.076	0.857
TD	GR	.150	0.749	.572	0.138	.238	0.570	.358	0.384
	SSR	-.253	0.584	.800**	0.017	.354	0.390	.091	0.830
	GLR	-.098	0.834	.713**	0.047	.295	0.478	.238	0.570
	RSB	-.145	0.756	.627	0.096	.303	0.466	.461	0.250
WALK	GR	-.252	0.586	.804**	0.016	.029	0.946	-.355	0.388
	SSR	-.395	0.381	.925**	0.001	-.043	0.919	-.069	0.871
	GLR	-.349	0.444	.888**	0.003	-.005	0.991	-.225	0.592
	RSB	-.408	0.364	.853**	0.007	.155	0.713	-.251	0.548
JOG	GR	.429	0.337	.654	0.079	.621	0.100	.587	0.126
	SSR	.080	0.864	.863**	0.006	.749**	0.032	.344	0.404
	GLR	.223	0.631	.786**	0.021	.688	0.059	.495	0.213
	RSB	.117	0.703	.697	0.055	.625	0.098	.611	0.108
LSR	GR	.256	0.579	.278	0.505	.097	0.820	.267	0.522
	SSR	-.170	0.716	.526	0.180	.207	0.623	-.129	0.760
	GLR	-.003	0.994	.426	0.293	.150	0.724	.073	0.864
	RSB	.023	0.961	.377	0.358	.169	0.690	.274	0.511
HSR	GR	.086	0.854	-.562	0.148	-.534	0.173	-.215	0.609
	SSR	-.246	0.596	-.365	0.374	-.535	0.172	-.354	0.389
	GLR	-.119	0.800	-.459	0.253	-.540	0.167	-.303	0.466
	RSB	-.157	0.736	-.504	0.203	-.506	0.201	-.164	0.699
SPRINT	GR	-.394	0.382	-.479	0.230	-.438	0.278	-.081	0.850
	SSR	-.458	0.301	-.383	0.349	-.541	0.166	.050	0.907
	GLR	-.445	0.317	-.432	0.285	-.491	0.216	-.016	0.970
	RSB	-.590	0.163	-.524	0.182	-.526	0.181	-.011	0.979
LIR	GR	-.151	0.746	.443	0.271	.457	0.255	.113	0.791
	SSR	-.281	0.541	.696	0.055	.581	0.131	-.200	0.634
	GLR	-.237	0.609	.597	0.118	.520	0.186	-.047	0.912
	RSB	-.159	0.733	.577	0.134	.559	0.150	.296	0.477
HIR	GR	-.147	0.753	-.575	0.136	-.578	0.133	-.609	0.109
	SSR	-.326	0.476	-.334	0.419	-.610	0.108	-.672	0.068
	GLR	-.263	0.569	-.447	0.267	-.599	0.116	-.681	0.063
	RSB	-.340	0.455	-.428	0.290	-.561	0.148	-.406	0.318

**= strong correlation
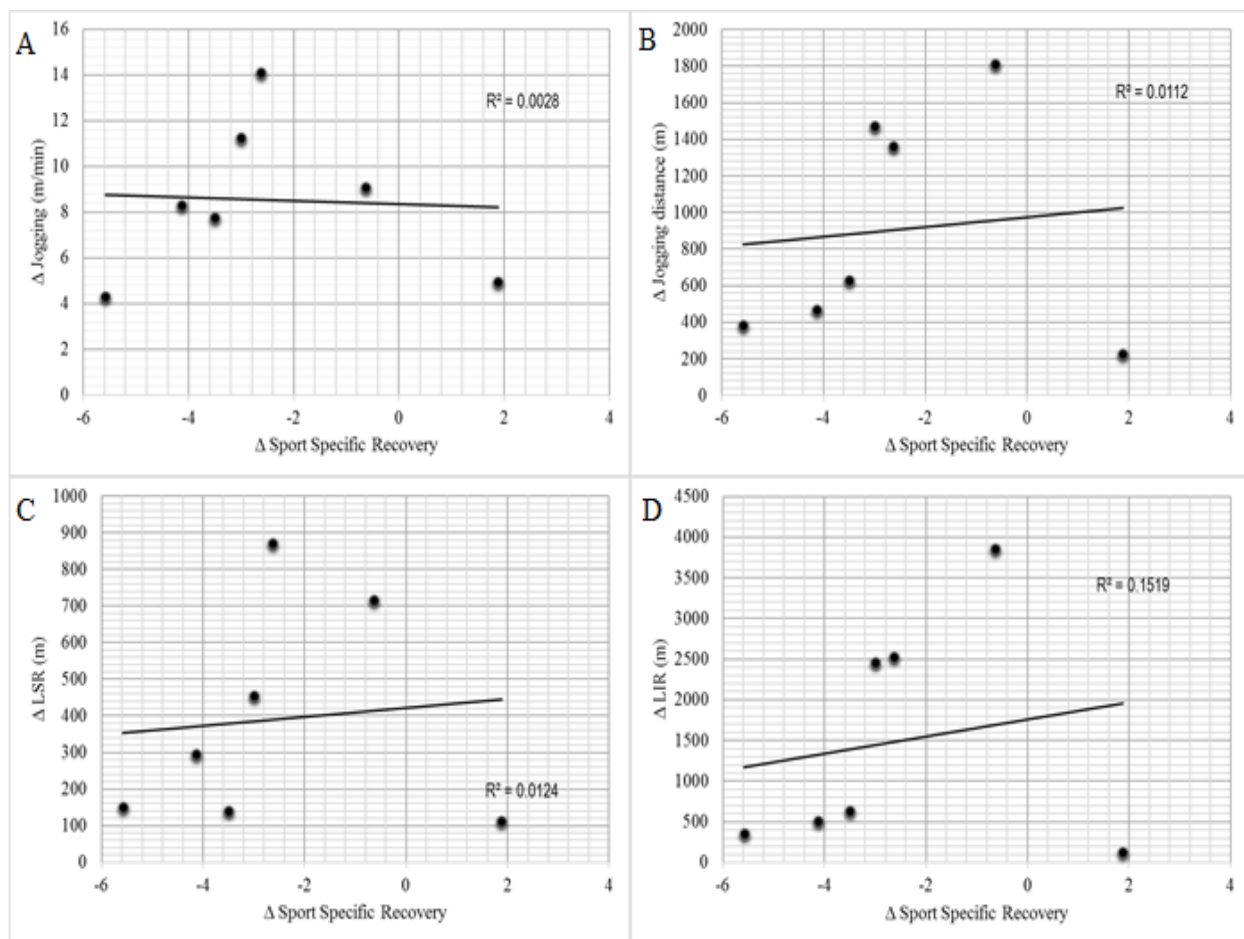
FIGURE 4. CORRELATIONS BETWEEN CHANGES FROM B1 TO B4 AND A) JOGGING DISTANCE RELATIVE TO MINUTES PLAYED, B) ABSOLUTE JOGGING DISTANCE, C) ABSOLUTE LOW SPEED RUNNING DISTANCE, AND D) ABSOLUTE LOW INTENSITY RUNNING DISTANCE COVERED DURING A MATCH.

CHAPTER 5: DISCUSSION

The results of this study indicate that running performance decreased across the competitive season. Total running distance tended to increase across the competitive season; however, this increase did not appear to indicate increased performance. Although not significant, a large effect was observed for minutes played across the season ($\eta^2_p = 0.22$), indicating that athletes played more minutes towards the end of the season. Subsequent analysis with dependent t-test indicated that minutes played during the second half of the season (B3 + B4) was significantly greater (p=0.033) than the first half of the season (B1 + B2). Further, strong positive correlations were observed between minutes played and total distance during B3 (r=.936) and B4 (r=.927), suggesting that the trend towards increased total distance across the season was a function of increased playing time, and not increased performance. Increases in total distance appeared to be accomplished via increased low velocity running distance, with no concomitant increase in distance covered at high-velocity. Consistent with this, significant increases in absolute jogging, low speed running, and low intensity running distance were observed, indicating increased reliance on lower intensity work to meet the demands of increased playing time during later stages in the season. Reductions in sport specific recovery were also observed between competitive blocks. Strong positive correlations were observed between high-velocity running distance and measures of stress from the RESTQ 52 Sport, particularly during the second and third competitive blocks. Strong positive correlations were observed between lower velocity running performance such as jogging distance and measures of recovery, particularly during B2. Further, strong negative correlations were observed between high velocity running performance and RESTQ recovery scales, while strong positive correlations were observed between measures of low velocity running performance relative to minutes played

and RESTQ recovery scales. These correlations appear to suggest that greater high-velocity running is associated with greater stress, while greater low velocity running is associated increased recovery. However, changes in running performance did not directly correlate with changes in sport specific recovery over time.

Our findings are in contrast to previous literature that has reported increases in high intensity running performance across a season (Mohr et al., 2003; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007; Silva et al., 2013). However, methodological differences may account for part of the discrepancy between these studies and the current study. Mohr et al. (2003) and Silva et al. (2013) utilized a different definition of high intensity running that included velocities greater than 4.17 m·s^{-1} (15 km·hr^{-1}), which is considerably lower than the definition used in the current study. Additionally, it was not reported in either study whether strength of opponent was different across time points, so the effect of opposition on running performance was not determined. Rampinini et al. (2007) did not report seasonal variations in low intensity running performance, making a complete interpretation of changes difficult. Further, these studies did not report changes in playing time or changes in running performance relative to minutes played. Consequently, to what extent playing time may have influenced running performance is unknown. As seen in the present study, increased playing time is likely a significant contributor to increased absolute distance. To our knowledge, only one other study has reported changes in running performance in conjunction with minutes played (Wells et al., 2015). Wells et al. (2015) examined changes in running performance of NCAA Division I female soccer players between regular and post-season competition. Similar to our findings, they observed significant increases in total distance, and low velocity running distance at the end of the season. However, a significant increase in minutes played was also noted, the effect of which

was considered very large. Strong positive correlations were observed between the change in minutes played and changes in both low-intensity running time and low-intensity running distance. Moreover, changes in high intensity running measures were not observed, indicating reduced performance in the latter stage of the season. Nevertheless, while Wells et al. argued that these findings were likely the result of fatigue, they did not report any physiological measures of stress or recovery.

In the present study, we observed a significant decrease in SSR during B4, which may account for the observed decrease in performance. Similar changes in recovery have been observed in a number of athletic populations. Nunes and colleagues (2014) observed significant reductions in the recovery-stress balance of professional basketball players during periods of increased training load towards the later point of a season. Similarly, Coutts et al. (2007) observed significant reductions in the recovery-stress state following intensified training periods in professional triathletes. In contrast to these observations, Meister et al. (2013) found no relationship between RESTQ scales and measures of performance in professional soccer players. However, this study divided players up according to whether they experienced high or low match exposure over a period of 3 weeks, and did not account for training volume. The associations between high-velocity running and increased stress, as well as low-velocity running and increased recovery in the present study appear to support the observations of both Nunes et al. (2014) and Lovell et al. (2010), suggesting that the RESTQ is a viable means of monitoring the stress and recovery of athletes in response to changes in training load, volume, and/or match performance. Nevertheless, corresponding increases in measures of stress were not observed during periods in which recovery is reduced, indicating a discordance between stress and recovery. These reductions also corresponded with increases in low intensity running measures,

which may indicate that measures of sport specific recovery are better indicators of running performance than measures of stress obtained from the RESTQ. Changes in SSR from B1 to B4 did not correlate with concomitant changes in running performance from B1 to B4. Therefore, while decreased SSR may have contributed to declines in running performance, the strength of the relationship between these variables seem to suggest that changes in stress and recovery are not a strong indicator of running performance.

One limitation of the current study was that only regulation 90-minute play was assessed. Two matches in the competitive season went into overtime, both during B2. These matches were separated by approximately 41 hours as part of a tournament, which previous research has shown may not allow for adequate recovery between games (McCormack et al., 2015). Therefore, it is possible that additional playing time and reduced recovery during B2 compared to other competitive blocks negatively impacted running performance during B2. Players may not have entered the tournament properly conditioned to handle additional playing time because overtime is not a typical occurrence in collegiate soccer. This may have contributed to the strength of relationships between running performance and stress and recovery measures during B2. Additionally, the small sample size used for this study make generalizations about results difficult to make. Lastly, while training load was assessed during games using Bioharnesses, loads placed on athletes during training was not accounted for, which is likely to significantly impact both stress and recovery levels. Therefore, future research should include measures of training load such as session RPE to quantify stress of training as well as competition.

The results of this study indicate that running performance declined across the season, with increased reliance on low intensity running as the season progresses in order to maintain match demands. While measures of stress do not differ across the season, sport specific recovery

appears to be reduced as the season progresses, which may indicate the accumulation of stress during the last competitive block of the season. However, changes in sport specific recovery were not correlated with changes in running performance, indicating that the RESTQ 52 Sport likely does not account for a significant portion of changes in running performance across a season. Future research should also incorporate the use of training load as well as in game performance measures in order to account for stress associated with training as well as games.

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APPENDICES

Appendix A
Figure 1A. Depiction of chest strap placement and biomodule orientation
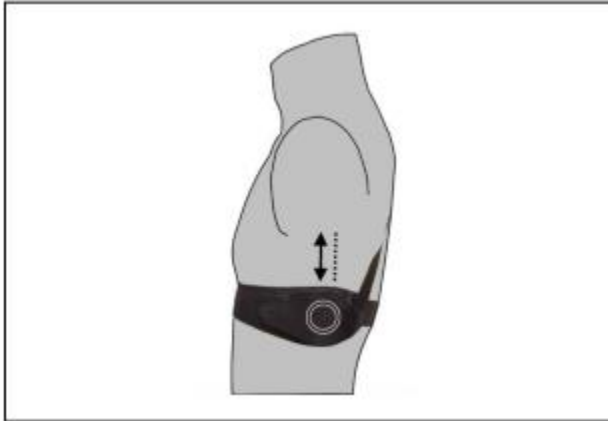
Figure 1B. Depiction of shoulder strap placement and GPS orientation
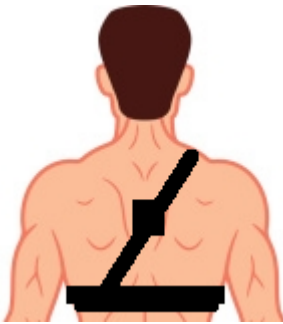
Appendix B

R E S T Q - 52 Sport

Single-Code: _____ Group Code: _____

Name (Last): _____ (First): _____

Age: _____ Gender: _____ Date: _____ Time: _____

Sport/Event(s): _____

This questionnaire consists of a series of statements. These statements possibly describe your psychic or physical well-being or your activities during the past few days and nights.

Please select the answer that most accurately reflects your thoughts and activities. Indicate how often each statement was right in your case in the past days.

The statements related to performance should refer to performance during competition as well as during practice.

For each statement there are seven possible answers.

Please make your selection by marking the number corresponding to the appropriate answer.

Example:

In the past (3) days/nights

... I read a newspaper

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

In this example, the number 5 is marked. This means that you read a newspaper very often in the past three days.

Please do not leave any statements blank.

If you are unsure which answer to choose, select the one that most closely applies to you.

Please turn the page and respond to the statements in order without interruption.

In the past (3) days/nights

1) ... *I watched TV*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

2) ... *I laughed*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

3) ... *I was in a bad mood*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

4) ... *I felt physically relaxed*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

5) ... *I was in good spirits*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

6) ... *I had difficulties in concentrating*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

7) ... *I worried about unresolved problems*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

8) ... *I had a god time with my friends*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

9) ... *I had a headache*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

10) ... *I was dead tired after work*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

11) ... *I was successful in what I did*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

12) ... *I felt uncomfortable*

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

In the past (3) days/nights

13) ... I was annoyed by others

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

14) ... I felt down

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

15) ... I had a satisfying sleep

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

16) ... I was fed up with everything

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

17) ... I was in a good mood

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

18) ... I was overtired

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

19) ... I slept restlessly

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

20) ... I was annoyed

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

21) ... I felt as if I could get everything done

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

22) ... I was upset

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

23) ... I put off making decisions

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

24) ... I made important decisions

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

In the past (3) days/nights

25) ... I felt under pressure

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

26) ... parts of my body were aching

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

27) ... I could not get rest during the breaks

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

28) ... I was convinced I could achieve my set goals during performance

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

29) ... I recovered well physically

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

30) ... I felt burned out by my sport

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

31) ... I accomplished many worthwhile things in my sport

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

32) ... I prepared myself mentally for performance

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

33) ... my muscles felt stiff or tense during performance

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

34) ... I had the impression there were too few breaks

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

35) ... I was convinced that I could achieve my performance at any time

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

36) ... I dealt very effectively with my teammates' problems

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

In the past (3) days/nights

37) ... I was in a good condition physically

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

38) ... I pushed myself during performance

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

39) ... I felt emotionally drained from performance

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

40) ... I had muscle pain after performance

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

41) ... I was convinced that I performed well

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

42) ... too much was demanded of me during the breaks

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

43) ... I psyched myself up before performance

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

44) ... I felt that I wanted to quit my sport

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

45) ... I felt very energetic

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

46) ... I easily understood how my teammates felt about things

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

47) ... I was convinced that I had trained well

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

48) ... the breaks were not at the right times

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

In the past (3) days/nights

49) ... I felt vulnerable to injuries

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

50) ... I set definite goals for myself during performance

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

51) ... my body felt strong

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

52) ... I felt frustrated by my sport

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

53) ... I dealt with emotional problems in my sport very calmly

0	1	2	3	4	5	6
never	seldom	sometimes	often	more often	very often	always

Thank you very much!

Appendix C

<table>
<tr><td colspan="3">Georgia Southern University
Office of Research Services & Sponsored Programs</td></tr>
<tr><td colspan="3">**Institutional Review Board (IRB)**</td></tr>
<tr><td>Phone: 912-478-0843

Fax: 912-478-0719</td><td>IRB@GeorgiaSouthern.edu</td><td>Veazey Hall 2021
P.O. Box 8005
Statesboro, GA 30460</td></tr>
</table>

To:	Nicholas Coker Dr. Adam Wells
From:	Office of Research Services and Sponsored Programs Administrative Support Office for Research Oversight Committees (IACUC/IBC/IRB)
Initial Approval Date:	01/31/2016
Expiration Date:	12/31/2016
Subject:	Status of Application for Approval to Utilize Human Subjects in Research – **Expedited**

After a review of your proposed research project numbered **H16165** and titled **"Relationship between stress, recovery and match performance in collegiate soccer players"** it appears that (1) the research subjects are at minimal risk, (2) appropriate safeguards are planned, and (3) the research activities involve only procedures which are allowable. You are authorized to enroll up to a maximum of __18__ subjects.

Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that the Institutional Review Board has approved your proposed research. Description: **This protocol will evaluate the relationship between in-game running performance and psychological subscales in male soccer players.**

If at the end of this approval period there have been no changes to the research protocol; you may request an extension of the approval period. Total project approval on this application may not exceed 36 months. If additional time is required, a new application may be submitted for continuing work. In the interim, please provide the IRB with any information concerning any significant adverse event, **whether or not it is believed to be related to the study**, within five working days of the event. In addition, if a change or modification of the approved methodology becomes necessary, you must notify the IRB Coordinator **prior** to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, you are required to complete a *Research Study Termination* form to notify the IRB Coordinator, so your file may be closed.

Sincerely,

Eleanor Haynes
Eleanor Haynes
Compliance Officer