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The Relationships Between Perceived Wellness, Sleep, and Acute: Chronic Training Load in National Collegiate Athletics Association Division I Male Soccer Players

Yasuki Sekiguchi,[1] Ryan M. Curtis,[1] Robert A. Huggins,[1] Courteney L. Benjamin,[1,2] Alan J. Walker,[3] Shawn M. Arent,[4,5] William M. Adams,[6] Travis Anderson,[6] and Douglas J. Casa[1]

[1]Department of Kinesiology, Korey Stringer Institute, University of Connecticut, Storrs, Connecticut; [2]Department of Kinesiology, Samford University, Birmingham, Alabama; [3]Department of Exercise Science, Lebanon Valley College, Annville, Pennsylvania; [4]Department of Exercise Science, University of South Carolina, Columbia, South Carolina; [5]IFNH Center for Health and Human Performance, Rutgers University, New Brunswick, New Jersey; and [6]Department of Kinesiology, University of North Carolina at Greensboro, Greensboro, North Carolina

Abstract

Sekiguchi, Y, Curtis, RM, Huggins, RA, Benjamin, CL, Walker, AJ, Arent, SM, Adams, WM, Anderson, T, and Casa, DJ. The relationships between perceived wellness of, sleep of, and acute: chronic training load on National Collegiate Athletics Association division I male soccer players. *J Strength Cond Res* 35(5): 1326–1330, 2021—The purpose of this study was to investigate relationships between perceived wellness, sleep, and acute: chronic workload ratio (ACWR) throughout a collegiate men's soccer season. Sixty male collegiate soccer players (mean[M] ± *SD*; age, 21±2 year; body mass, 77.6 ± 6.5 kg; height, 180.1 ± 6.4 cm; body fat%, 9.9 ± 3.9% ; and $\dot{V}O_2max$, 53.1 ± 5.0 ml·kg^{-1}·min^{-1}) participated in this study. During each session, players used a heart rate and global positioning satellite–enabled chest strap to measure training impulse and ACWR. The ACWR values were trichotomized at the individual level giving an equal number of observations within each ACWR category of low, moderate, and high ACWR (M ± *SD*; low, 0.658 ± 0.23; moderate, 0.92 ± 0.15; and high, 1.17 ± 0.16). Stress, fatigue, and soreness levels were collected using 1–10 Likert scales and sleep duration, and sleep quality were measured by the Karolinska Sleep Diary. Stress, fatigue, soreness levels, and sleep quality were transformed to corresponding z-scores at the individual level. Fatigue levels were significantly higher when ACWR was high compared with low (mean difference [95% confidence intervals], effect size, *p*-value; 0.31 [0.21, 0.42], 0.29, $p < 0.001$) and moderate (0.14 [0.03, 0.24], 0.13, $p = 0.01$). Fatigue levels were also significantly higher when the ACWR was moderate compared with low (0.18 [0.07, 0.28], 0.16, $p = 0.001$). Soreness levels were significantly higher when the ACWR was high compared with low (0.25 [0.14, 0.36], 0.23, $p < 0.001$). Stress levels were significantly greater when the ACWR was high compared with low (0.19, [0.08, 0.29], 0.18, $p < 0.001$) and compared with moderate (0.15, [0.05, 0.25], 0.14, $p = 0.004$). There were no differences in sleep duration or sleep quality in different ACWR. The ACWR may be a useful tool to achieve an appropriate balance between training and recovery to manage daily fatigue and soreness levels in athletes.

Key Words: athlete performance, athlete monitoring, perception, recovery

Introduction

Athlete training loads (internal and external workloads; such as training impulse [TRIMP], distance, and heart rate [HR] measurements), perceived ratings of wellness (such as stress, fatigue, and soreness levels), and sleep are important measures for coaches, sports scientists, and clinicians to monitor when prescribing training and recovery. Adjusting training and recovery allows the athlete to be as prepared as possible and in good condition for an upcoming match (23). Objective markers of training load and perceived ratings of wellness are routinely used for daily and season-long monitoring in soccer players (4). It is also demonstrated sleep duration and sleep quality are important factors for recovery and adaptations from training, and those are associated with competitive success (21). Thus, perceived ratings of wellness, sleep, and tracking training load can be useful tools to optimize performance in soccer players.

The relationships between training load and perceived ratings of wellness have been reported previously in team sports athletes (5,18,23). Thorpe et al. monitored training load measured by session rating of perceived exertion, morning rating of fatigue, delayed-onset muscle soreness (DOMS), and HR-derived indices in English Premier League players for 3 weeks (18). They concluded monitoring perceived fatigue and DOMS were more sensitive to daily fluctuations of training load than HR-derived indices (18). Other research reported that there was a correlation between objective and subjective fatigue and weekly accumulated distance covered (23). In addition, Elloumi et al. (5) demonstrated fatigue levels were increased after 6 weeks of an intense training period and decreased after 2 weeks of a recovery period. These findings suggest that perceived ratings of wellness, such as fatigue and soreness levels, may be a sensitive to changes in training load and useful for monitoring stress-recovery balance (5).

Address correspondence to Yasuki Sekiguchi, yasuki.sekiguchi@uconn.edu.

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In addition to perceived ratings of wellness, some investigations determined relationships exist between sleep duration, sleep quality, and training load. Watson et al. (20) concluded that increased training load was associated with decreased sleep duration and sleep quality in female soccer players. Another study by Pithford et al. (13) also found sleep duration and quality to be sensitive to changes in training load in Australian football players. In addition to these studies, monitoring sleep quality was shown to be sensitive to daily fluctuations of training loads in elite soccer players (18). Interestingly, improvement in sleep duration and sleep quality were associated with increased chances of competitive success in team sports (21). These findings related to sleep and training load are critical to those teams who are actively exploring and refining the habits of their players to best optimize athletic performance as well as health and well-being.

Although previous studies have examined the relationships between absolute training load and perceived ratings of wellness and sleep, monitoring absolute training load fails to take into account the chronic load of the athlete (15). The acute: chronic work load ratio (ACWR) has been introduced to track training load in athletes (6). The acute :chronic work load ratio expresses the acute training load (e.g., sum of previous 7 days training load) relative to the chronic training load (e.g., sum of previous 28 days training load) (3). When the chronic training load is high and the acute training load is low, the athlete can experience relatively lower fatigue and higher readiness (15). However, when the acute training load is high and the chronic training load is low, increased levels of fatigue occur (15). Therefore, the ACWR may provide more practical and useful information to coaches and sports scientists compared with absolute training load when monitoring stress and recovery. However, no known literature exists examining the association between perceived ratings of wellness, sleep, and ACWR. Thus, the purpose of this study was to investigate relationships between daily stress, fatigue and soreness levels, as well as sleep duration and sleep quality and ACWR, calculated by TRIMP throughout a collegiate men's soccer season.

Methods

Experimental Approach to the Problem

Data collection was performed in different teams in 2016 and 2017 with 3 separate men's teams, and no players were involved in both years. After the study's procedures, risks, and benefits of the study were explained, subjects provided written and informed consent to participate in this study which was approved by the university's institutional review board.

Subjects

Sixty National Collegiate Athletics Association (NCAA) Division 1 male collegiate soccer players (Age range [18-23]; mean [M] $\pm$ *SD*; age, 21$\pm$2 y; body mass, 77.6 $\pm$ 6.5 kg; height, 180.1 $\pm$ 6.4 cm; body fat%, 9.9 $\pm$ 3.9%; and $\dot{V}O_2max$, 53.1 $\pm$ 5.0 $ml \cdot kg^{-1} \cdot min^{-1}$) participated in this study, which took place during the 2016 and 2017 NCAA soccer season from preseason to postseason. Data collection was performed in different teams in 2016 and 2017 with 3 separate men's teams, and no players were involved in both years. After the study's procedures, risks, and benefits of the study were explained, subjects provided written and informed consent to participate in this study which was approved by the University of Conneticut university's institutional review board.

Procedures

For each training session and match throughout the season, each subject's training load was collected with a 10 Hz HR and global positioning satellite and 200 Hz microelectromechanical-enabled player tracking device (Polar Team Pro, Polar Electro, Lake Success, NY). Monitored training load was time spent in different HR zones relative to the maximum HR. Based on these data, TRIMP was calculated using the Edwards method (14). When subjects did not have a training session or match, training load for the day was classified as "0" (8). The ACWR was calculated for TRIMP using the ratio of the previous 7-day rolling average to the previous 28-day rolling average. First 27 days of data were removed from the analyses because 28-day rolling average could not be calculated. Acute:chronic workload ratio values were trichotomized at the individual level giving an equal number of observations within each ACWR category for each player. Categories were subsequently defined as low, moderate, and high ACWR (M $\pm$ *SD*; low, 0.66 $\pm$ 0.23; moderate, 0.92 $\pm$ 0.15; and high, 1.17 $\pm$ 0.16).

In addition to training load, each subject's stress, fatigue, and soreness levels were measured throughout the season. Before each scheduled training session and match, subjects signed into a tablet or smartphone application where they reported stress, fatigue, and soreness level scales using a 1–10 Likert scale. Also, subjects reported sleep status each day throughout the season. Sleep duration was determined using self-reported bed time and wake time, and sleep quality was determined by asking subjects to answer "how well did you sleep?" on a 1–5 Likert scale using the Karolinska Sleep Diary (1).

Statistical Analyses

Stress, fatigue, soreness levels, and sleep quality were transformed to corresponding z-scores to standardize the mean value (i.e., 0) across all individuals. Data were presented as M $\pm$ *SD*, mean differences (MDs) and 95% confidence intervals (95% CIs). The effect size (ES) was also calculated by Hedges δ_T (19). Despite the differences in derivation, the resulting effect sizes were interpreted similarly to other mean difference effect size calculations: trivial (0–0.19), small (0.2–0.49), medium (0.5–0.79), or large (>0.8) effects to show the magnitude of differences (11). Linear mixed-effect models were used to assess the differences in soreness, stress, fatigue, sleep quality, and sleep duration across the ACWR categories of low, moderate, and high. Random effects were defined as intercept only, as more complex model random effects structures failed to converge. All models were visually inspected for normality and homoscedasticity and were assessed to meet model assumptions. Statistical analyses were performed using R Statistical Software (CITE: R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/). Significance was set at a priori at $p \leq 0.05$.

Results

Figures 1–3 illustrates the differences among z-score stress, fatigue, and soreness levels by low, moderate, and high ACWR groups. All data presented as (MD [95% CI], ES; *p*-value). Stress levels were significantly greater for high ACWR compared with low (0.19 [0.08, 0.29], 0.18, $p < 0.001$) and compared with moderate (0.15 [0.05, 0.25], 0.14, $p = 0.004$). Stress levels were not different between moderate and low ACWR (0.04 [−0.07, 0.14], 0.04, $p = 0.499$). Fatigue levels were significantly higher when the ACWR was high compared with low (0.31 [0.21, 0.42], 0.29, $p < 0.001$) and moderate (0.14 [0.03, 0.24], 0.13, $p = 0.01$). Fatigue levels were also significantly higher when the

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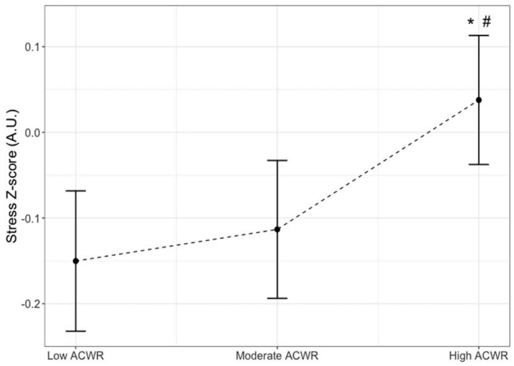

Figure 1. Predicted stress z-score levels for trichotomized acute: chronic work load ratio (ACWR). *significantly different from low ACWR, #significantly different from moderate ACWR ($p < 0.05$).

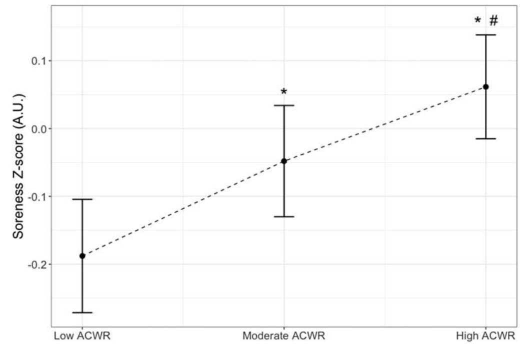

Figure 3. Predicted soreness z-score levels for trichotomized acute: chronic work load ratio (ACWR). *Significantly different from low ACWR, #significantly different from moderate ACWR ($p < 0.05$).

ACWR was moderate compared with low (0.18 [0.07, 0.28], 0.16, $p = 0.001$). Soreness levels were significantly higher when the ACWR was high compared with low (0.25 [0.14, 0.36], 0.23, $p < 0.001$) and when compared with moderate (0.11 [0.00, 0.22], 0.10, $p = 0.042$). Soreness levels were also significantly higher when the ACWR was moderate compared with low (0.14 [0.03, 0.25], 0.13, $p = 0.013$).

Figures 4 and 5 illustrate the model estimates for sleep duration and sleep quality at low, moderate, and high ACWR groups. Sleep duration was not different when the ACWR was high compared with low (−4.83, [−15.95, 6.30], 0.04, $p = 0.395$), high compared with moderate (−0.19, [−11.47, 11.09], 0.001, $p = 0.974$), or moderate compared with low (−4.64, [−15.88, 6.60], 0.04, $p = 0.418$). There were no significantly differences in sleep quality between high and low (0.00 [−0.10, 0.11], 0.004, $p = 0.938$), high and moderate (−0.06 [−0.18, 0.05], 0.07, $p = 0.251$), and moderate and low (0.07 [−0.04, 0.18], 0.07, $p = 0.218$).

Discussion

The purpose of this study was to investigate the relationships between daily stress, fatigue, soreness levels, sleep duration, sleep quality, and ACWR throughout a collegiate men's soccer season. During periods of high ACWR (1.17 ± 0.16), stress, fatigue, and soreness levels were significantly greater compared with moderate (0.92 ± 0.15) and low (0.66 ± 0.23). In addition, fatigue levels were significantly higher when the ACWR was moderate compared with low. Monitoring training load and assessing perceived ratings of wellness and sleep in athletes are important for coaches and sports scientists prescribing training and recovery (9). To the best of our knowledge, this was the first study to explore the relationships between daily stress, fatigue, soreness levels, sleep duration, sleep quality, and the ACWR throughout a collegiate men's soccer season.

The ACWR may be an important factor to consider when contextualizing athletes' daily perceived rating of wellness. In the current study, when the ratio of the previous 7-day average to the previous 28-day average in the ACWR was high, players perceived higher fatigue and soreness levels. Previous investigations examining the relationships between daily training load and fatigue in English Premier League soccer players in season competitive phases demonstrated perceived ratings of fatigue were sensitive to daily fluctuations in total high-intensity running distance (17). Furthermore, total perceived fatigue simultaneously increased with increases in training load, meaning that this short and practical questionnaire of "how fatigued do you feel?" was a sensitive and practical tool to track changes in the training load in team sports players (5). These previous studies support the current findings, which were fatigue levels were significantly higher when ACWR was high compared with low and moderate. However, these previous studies monitored absolute training load, which did not take into account the chronic load of the athlete (15). The current investigation indicated the ACWR influenced daily fatigue level, suggesting the importance of monitoring both

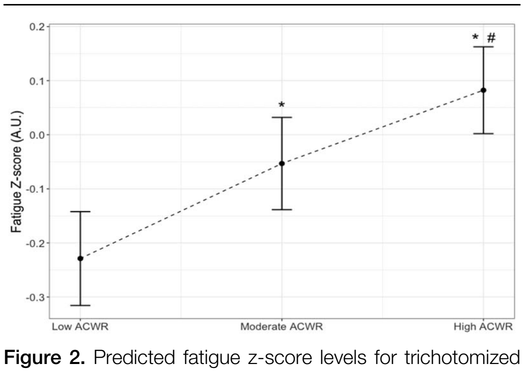

Figure 2. Predicted fatigue z-score levels for trichotomized acute: chronic work load ratio categories (ACWR). *Significantly different from low ACWR, #significantly different from moderate ACWR ($p < 0.05$).

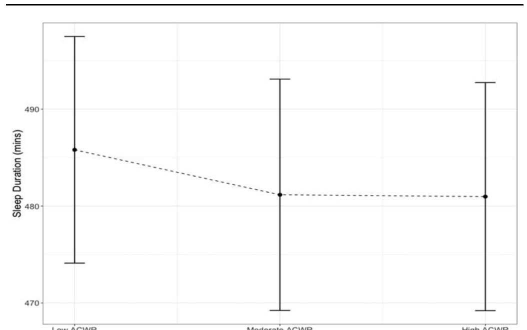

Figure 4. Predicted sleep durations for trichotomized acute: chronic work load ratio (ACWR).

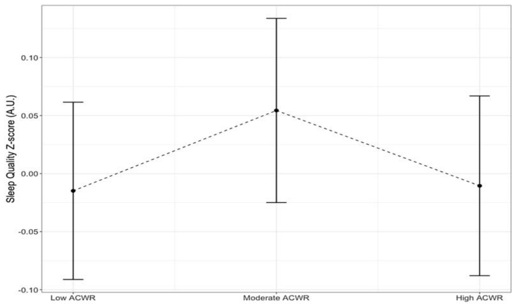

Figure 5. Predicted stress z-score sleep quality levels for trichotomized acute: chronic work load ratio (ACWR).

acute and chronic training load. When acute training load is higher than the level in which the player is prepared to tolerate, this eventually leads to fatigue because of negative training-stress balance (8,15).

Although there were significant differences, the magnitude of the difference was small or trivial, which means that changes in the ACWR only produced small or trivial changes. Although perceived wellness seem to be sensitive to changes in relative workload, other factors such as social, lifestyle, and athlete-coach relationships can add to the stress experienced by athletes, and therefore may be confounding the perceived wellness-ACWR relationship (7). In addition, coursework demands, study-life balance, and financial strain are known as stressors for collegiate athletes, so these factors must also be considered when assessing wellness and the relationship to ACWR (16).

The ACWR did not seem to greatly influence sleep duration and sleep quality. Previous studies examining the relationships between sleep duration, sleep quality, and training load have shown conflicting results (10,18,22). Variations in daily perceived training load did not alter sleep duration, monitored by actigraphy, and one-channel EEG recordings in elite athletes during 7 days of regular training (10). However, greater high speed running in youth soccer players has shown to increase total sleep time, monitored by commercial wireless sleep monitor, during 14 days of in-season period (22). In addition, an investigation by Thorpe et al. indicated sleep quality was sensitive to the daily fluctuations of training load (18). Nevertheless, a review concluded that increased exercise intensity or duration did not disrupt sleep quality (12). It is important to note that these studies investigated the effect of acute training load, not the ACWR on sleep duration and sleep quality. When both acute and chronic are taken into account, training load might not impact sleep duration and sleep quality as the current study examined. When chronic workload is consistently low, the likelihood of there being an acute bout is increased which in turn would lead to a high ACWR. It is in situations such as these, where chronic workload is low and suddenly acute loads are high, where sleep duration might prove to be most critical for the purposed of recovery.

The limitation of this study is that stress, fatigue, soreness levels, sleep duration, and sleep quality questionnaires were collected before any sessions by self-report. Also, given that some subjects may have been training throughout the summer (unofficial team practices before preseason started) leading into the fall competitive season, this summer training was not captured in the current data set and their training history. Thus, first 27 days of data were removed from the analyses because the ACWR could not be calculated using a 7:28 days rolling average. In addition, as mentioned above, there may be other factors that could have influenced the perceived ratings of wellness and sleep other than the ACWR. For example, Benjamin et al. indicated training schedule impacted sleep duration and sleep quality in collegiate student-athletes (2). Further studies are needed to investigate the comprehensive effects of multiple variables on stress, fatigue, soreness levels, sleep duration, and sleep quality in athletes.

In conclusion, high ACWR-induced changes in daily stress, fatigue, and soreness levels compared with low and moderate ACWR, indicating the importance of monitoring both chronic and acute training loads. Coaches and sports scientists may be able to use the ACWR to make plans of training and recovery to achieve an appropriate balance between training and recovery to manage daily stress, fatigue, and soreness levels in athletes.

Practical Applications

Monitoring the ACWR may be a useful tool to manage perceived rating of wellness in soccer player. Changes in the ACWR might only produce trivial or small changes in perceived rating of wellness, although small changes might be still important for players. Coaches and sport scientist may keep the ACWR low when stress, fatigue, and soreness levels need to be lower.

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