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MOVEMENT DEMANDS AND PERCEIVED WELLNESS ASSOCIATED WITH PRE-SEASON TRAINING CAMP IN NCAA DIVISION I COLLEGE FOOTBALL PLAYERS

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ABSTRACT

The aims of the present study were to examine the movement demands of pre-season practice in National Collegiate Athletic Association (NCAA) division I college football players using portable global positioning system (GPS) technology and to assess perceived wellness associated with pre-season practice to determine if GPS-derived variables from the preceding day influence perceived wellness the following day. Twenty-nine players were monitored using GPS receivers (Catapult Innovations, Melbourne, Australia) during 20 pre-season practices. Individual observations (n=550) were divided into offensive and defensive position groups. Movement variables including low-, medium-, high-intensity, and sprint distance, player load, and acceleration and deceleration distance were assessed. Perceived wellness ratings (n=469) were examined using a questionnaire which assessed fatigue, soreness, sleep quality, sleep quantity, stress, and mood. A one-way ANOVA for positional movement demands, and multi-level regressions for wellness measures were used, followed by post-hoc testing to evaluate the relational significance between categorical outcomes of perceived wellness scores and movement variables. Results demonstrated significantly ($p<0.05$) greater total, high-intensity, and sprint distance, along with greater acceleration and deceleration distances for the DB and WR position groups compared to their respective offensive and defensive counterparts. Significant ($p<0.05$) differences in movement variables were demonstrated for individuals who responded more or less favorably on each of the six factors of perceived wellness. Data from the present study provide novel quantification of the position-specific physical demands and perceived wellness associated with college football pre-season practice. Results support the use of position-specific training and individual monitoring of college football players.

Key Words: GPS, Monitoring, Questionnaire, American football

INTRODUCTION

American college football is a physically demanding, full-contact team sport in which players are required to participate in competition necessitating high levels of muscular strength, power, speed and agility, and repeated high-intensity movements (40). In addition to the intense movement demands associated with American football, athletes are exposed to frequent collisions and blunt force trauma associated with repeated contact with opponents and the ground during tackling, blocking, and ball-carrying activities (43). Recent studies (16,39,48) have added to our knowledge of player movement characteristics during National Collegiate Athletic Association (NCAA) division I football competition providing an increased understanding of the positional movement profiles, including the quantification of sprint distances and high-intensity accelerations and decelerations, in addition to a basic understanding of exercise to rest ratios. An additional investigation (49) of NCAA division I college football has revealed the frequency and intensity of impacts and rapid changes of direction, and provided a quantification of the position-specific number and intensity of impacts per game. The movement patterns of NCAA division I football players during competition using global positioning systems (GPS) technology have been reported (48), however limited data (8) exist describing the movement profiles experienced by players during pre-season training camp, that are synonymous with college football competition.

The development of GPS technology with integrated triaxial accelerometers (IA) have provided a means of quantifying the physical demands of training and competition in contact team sports (1,11,33,48). Improvements in GPS technology have resulted in improved accuracy (17), and have provided a valid and reliable means of assessing activity profiles in team sports (6,19,20,47). Additionally, IA have demonstrated reliability (3) as a means of measuring physical activity across multiple players in team sports, and strong inter-unit relationships (r=0.996-0.999) have been demonstrated during high-intensity contact team sport activity.

College football teams that are similar to other collision-based team sports (5,23), participate in an intensified pre-season training camp that typically commences 4-5 weeks prior to the first competition and is associated with a maximum of 29 practice sessions (34). National Collegiate Athletic Association rules govern practice guidelines, permitting teams to designate up to four days for multiple practices, provided the practices do not exceed 5 total hours combined, and they do not occur on consecutive days (34). Programming training loads during the pre-season practice period which maximize positive physiological adaptations, and minimize excessive fatigue that may be associated with maladaptation, can be challenging for coaches and performance staff. While the programming of individual training load prescriptions presents a difficulty in team sports, the prudent monitoring of the individual response to these loads is fundamental for maximizing positive training adaptations (2).

Monitoring training load involves not only objectively quantifying the volume, intensity, and duration of physical activity completed, commonly referred to as external load, but also the internal load, or the relative physiological and psychological stress imposed as a result of training (13). Previous research in contact team sport, with competitive demands indicative of NCAA division I football, has examined potential measures of an athlete’s internal response, including perceived wellness, and the biochemical, and neuromuscular response to training and competition (30,46), however ambiguity exists as to the methods that may be most pertinent to quantify this response (13).

Subjective measures of mood state and well-being are efficient, inexpensive, and non-invasive (28), have demonstrated sensitivity to training stress, exhibiting a dose-response relationship with training load (38,42), and have been established to be as effective as objective measures in identifying training stress (22). In elite contact team sport, significant correlations have been reported between fluctuations in daily training load and changes in subjective ratings of wellness (4). During intensified periods of competition in sports characteristic of American football, significant changes in perceived well-being accompany performance decrements, decreases in neuromuscular power, and increases in biochemical markers of muscle damage (18).

There exist a small number of subjective questionnaires that have demonstrated accuracy in assessing athletes' response to training and competition loads including the Recovery-Stress Questionnaire for Athletes (RESTQ-Sport) (21), Athlete Burnout Questionnaire (ABQ) (37), and Daily Analysis of Life Demands for Athletes (DALDA) (41) among others. Due to the comprehensive and time-consuming nature of the subjective questionnaires commonly used to monitor athletes' internal training response, the practicality of their implementation presents considerable logistical challenges in a high-performance applied setting (45). A survey of the current trends in fatigue monitoring among Australian and New Zealand high-performance sport revealed that 84% of respondents used self-report questionnaires, 80% of which were custom designed forms consisting of 4-12 items (44). Consequently, it has been recommended that coaches and performance staff utilize brief, customized questionnaires, similar to the one employed by McLean et. al (33) within an athlete monitoring system (15).

Despite recent advances in our understanding of movement characteristics associated with competition, GPS-derived movement characteristics of multiple position groups resulting from pre-season training camp practices in NCAA division I football players remain unknown. Additionally, the effects of pre-season training camp practice loads that are commonly undertaken in division I college football on the subjective perceptions of wellness are unclear. A more comprehensive understanding of the physiological demands and the resulting subjective psychological response associated with pre-season training camp practice will augment our understanding of the demands of NCAA football players, providing performance coaches a platform to develop training programs that replicate the physical demands of training camp, and allow for the individualization of practice training loads and recovery strategies to enhance performance throughout the pre-season period. The aim of the present study was (a) to examine the positional movement demands associated with pre-season training camp practices in NCAA division I college football players using portable GPS and IA technology and (b) to assess daily perceived wellness associated with pre-season training camp utilizing a custom-designed questionnaire to determine if GPS-derived measures from the preceding day influence perceived ratings of wellness on the following day. We hypothesized that there will be substantial positional differences in the movement demands of NCAA division I football players during pre-season training camp practice, in addition to substantial differences in perceived wellness scores based on the movement demands resulting from practice on the previous day.

METHODS

EXPERIMENTAL APPROACH TO THE PROBLEM

To examine the positional movement characteristics during NCAA division I football pre-season training camp, portable GPS and IA data were collected from players during 20 pre-season practices completed over the course of 20 days. Each individual GPS and IA dataset was divided into specific positional groups for the offense that included wide receivers (WR, 91 observations), quarterbacks (QB, 19 observations), running backs (RB, 40 observations), tight ends (TE, 53 observations), offensive linemen (OL, 80 observations), and for the defense that included defensive backs (DB, 100 observations), linebackers (LB, 80 observations), defensive ends (DE, 40 observations) and defensive tackles (DT, 47 observations). To determine positional movement profiles, each practice completed was assessed as a single observation.

To assess perceived wellness associated with pre-season training camp practices, a custom designed form (30) was completed by participants every morning prior to any physical activity. A total of 469 observations were included in present examination which included 78 WR observations, 16 QB observations, 34 RB observations, 46 TE observations, 68 OL observations, 85 DB observations, 68 LB observations, 34 DE observations, and 40 DT observations. For the purposes of examining perceived wellness associated with pre-season camp, only practice data where a survey was completed on the following day, were included in the analysis. For days where two practices occurred, and a survey was taken the following day, both practices were aggregated. Two practices occurred on three separate days, namely days 6, 8, and 13 of pre-season training camp. The first two practices of pre-season training camp were completed in helmets only, and therefore were omitted from the analysis.

SUBJECTS

Twenty-nine National Collegiate Athletic Association (NCAA) Division I Football Bowl Subdivision (FBS) football players (age 20.6 ± 1.1 years; age range 18.3 – 22.8; height 187.9 ± 6.5 cm; and mass 108.9 ± 19.8 kg) participated in the present study. Positional anthropometric data are presented in Table 1. All subjects were collegiate athletes whom had been selected to participate in the football program prior to the commencement of the study. All participants in the present study completed the teams' summer off-season physical development training program that included a full-body strength and power training program and specific skills and conditioning sessions designed to simulate the demands of NCAA division I college football practice. The present study comprises the statistical analysis of data collected as part of the day to day student athlete monitoring and testing procedures within the university's football program. Ethical approval was obtained from the university's Institutional Review Board and all subjects signed an institutionally approved informed consent document prior to participating in the study.

PROCEDURES

Global Positioning System Units. Positional movement data were collected in 20 practice sessions using a commercially available GPS unit which sampled at 10 Hz (MinimaxX S5; Catapult Innovations, Melbourne, Australia). The unit included a triaxial accelerometer (IA) which operated at 100 Hz and assessed the frequency and magnitude of full-body acceleration ($m \cdot second^{-2}$) in three dimensions, namely, anterior-posterior, mediolateral, and vertical (24,32). Prior to the commencement of each practice, GPS receivers were placed outside for 15 minutes to acquire a satellite signal, after which, receivers were placed in a custom designed pocket attached to the shoulder pads of the subjects. Shoulder pads were custom-fit for each individual, thereby minimizing movement of the pads during practices. The GPS and IA receivers used in the present study were positioned in the center of the upper back, slightly superior to the scapulae. Subjects were outfitted with the same GPS receiver for each of the 20 practices. Following the completion of practices, GPS receivers were removed from the shoulder pads, and subsequently downloaded to a computer for analysis utilizing commercially available software (Catapult Sprint 5.1, Catapult

Innovations, Melbourne, Australia). Combined tri-axial accelerometer data were presented as PlayerLoad™ (PL), which is a modified vector magnitude expressed as the square root of the sum of the squared instantaneous rates of change in acceleration in each of the three planes and divided by 100 (3). Boyd and colleagues (3) have demonstrated the intra-unit (0.91-1.05 % coefficient of variation [CV]) and inter-unit (1.02-1.10 % CV) reliability of PL and determined its inter-unit reliability in Australian Rules Football matches (1.90% CV). Data provided from GPS receivers were assessed as movement profiles variables including total, low-intensity, medium-intensity, high-intensity, and sprint running distances (m), acceleration and deceleration distances (m), and PL (arbitrary units). Classifications of parameters of movement profile variables are described below and presented in Table 2. Each of the GPS and IA variables measured in the present study was calculated using commercially available software (Catapult Sprint 5.1, Catapult Innovations, Melbourne, Australia).

Movement Classification System. Movement profile classifications have been described for game analysis in American football (48) and similar contact team sports (31,33). The classification profile utilized in the present study was selected by the researchers to more accurately reflect the demands of American football (48). Each movement classification was coded as one of four speeds of locomotion (Table 2). Low-intensity movements, such as standing, walking and jogging, were considered to be 0 – 12.9 $km \cdot h^{-1}$, medium-intensity movements, such as striding and running, were considered to be 13.0 – 19.3 $km \cdot h^{-1}$, high-intensity movements, such as fast running for some positional groups, and sprinting for others, were classified as 19.4 – 25.8 $km \cdot h^{-1}$, and sprinting movements were classified as exceeding 25.8 $km \cdot h^{-1}$. Short duration high-intensity movements, or measures of acceleration and deceleration, were classified as four groups, specifically low-intensity (0 – 1.0 $m \cdot s^{-2}$), medium-intensity (1.1 – 2.0 $m \cdot s^{-2}$), high-intensity (2.1 – 3.0 $m \cdot s^{-2}$), and maximal-intensity (> 3.0 $m \cdot s^{-2}$).

Wellness Questionnaire. During pre-season training camp, athletes completed a daily wellness questionnaire based on prior recommendations by Hooper and Mackinnon (15) and previous research in Rugby League, both during intensified periods of training and following competition (18,30,46). This approach to athlete monitoring is consistent with survey data outlining the fatigue-monitoring practices utilized within high-performance sport in Australia and New Zealand (44). The questionnaire utilized in the present study assessed six factors of perceived wellness including fatigue, soreness, sleep quality, sleep quantity, stress, and mood on a 1-5 Likert scale in one-point increments, with higher scores representing more favorable responses (Figure 1). The questionnaire was completed via pen and paper every day before breakfast between 7:00 am and 9:00 am, prior to any physical activity, and subsequently downloaded to a laptop for analysis. Similar scales have been shown to have good reliability and validity (7).

STATISTICAL ANALYSES

The movement metrics selected for categorization in this study, along with all subjective ratings, were used to perform multiple statistical models to capture the statistical analyses necessary for the two main aims of this paper. All models were assessed using the movement metrics as the outcome variable.

Positional Movement Demands. Descriptive statistics were presented as mean ± standard deviation (SD) for each practice throughout training camp, and Pearson's Correlation was completed to determine the magnitude and direction of covariance across all movement metrics used in this study. Following calculation of descriptive statistics, a one-way ANOVA was conducted for each movement metric to determine if the positions within the offensive and defensive teams had significant differences in each metric. To account for the unbalanced nature of this data, a post-hoc Tukey-Kramer test was used to establish significance across offensive and defensive positions. Statistically significant ($p<0.05$) differences within the offensive and defensive teams are listed in table 3 and 4.

Perceived Wellness. A series of random effects multi-level regressions, set at the individual and day level, were used to determine the differential effect of specific movement metrics from the previous day on perceived wellness ratings the following day. Categorical outcomes were used to determine less favorable responses (1-2), neutral responses (3), and more favorable responses (4-5) to account for the possibility of non-linear relationships with varying outcomes. Setting the data at the individual and day level allowed for the use of a multi-level model, which mitigates the nested structure of the data within a single day. Following the completion of the regressions, post-hoc testing including t-tests and Wald tests were used to determine relational significance between different categorical outcomes. Significance in all tests was measured at three levels; $p<0.05$, $p<0.01$, and $p<0.001$. The statistical means ± SD, regression coefficients, and 95% confidence intervals are presented in tables 5-7, and controlled for positional variation. All statistical analyses were performed using Stata Statistical/Data Analysis Software (Stata 14 for Windows, version 14.1; StataCorp, College Station, TX, USA).

RESULTS

Positional Movement Demands

Defense: The characteristics of movement patterns for defensive position groups are outlined in Table 3. Significant ($p<0.05$) differences were reported for several movement variables measured in the present study for defensive position groups. The DB position group accrued significantly ($p<0.05$) greater PL, total distance, low-intensity, high-intensity, and sprint running distance than all other defensive position groups. The LB position group demonstrated significantly ($p<0.05$) greater PL, total, low-intensity, medium-intensity, and high-intensity distance than both the DE and DT position groups. The DB position group accrued significantly ($p<0.05$) more acceleration and deceleration distance, in all zones of intensity, than all other defensive position groups. The LB position group demonstrated significantly ($p<0.05$) greater acceleration and deceleration distance, in all zones of intensity, than the DT and DE groups, except for max-intensity acceleration distance, when compared to DE.

Insert Table 3 Here

Offense: The characteristics of movement patterns for offensive position groups are outlined in Table 4. Significant ($p<0.05$) differences were reported for several movement variables measured in the present study for offensive position groups. The WR position group demonstrated significantly ($p<0.05$) greater total, medium-intensity, high-intensity, and sprint distance than all other offensive position groups, and significantly ($p<0.05$) higher PL than all offensive groups, except for the QB. Additionally, the WR group achieved significantly ($p<0.05$) greater low-, medium, and high-intensity acceleration and deceleration distance than all other offensive position groups, while the RB group demonstrated significantly ($P<0.05$) higher high-intensity and max-intensity deceleration distance than the QB, TE, and OL groups. The OL position group accrued significantly ($p<0.05$) less total and high-intensity distance, and significantly ($p<0.05$) less acceleration and deceleration distance, at all intensities, than every other offensive position group.

Insert Table 4 Here

Perceived Wellness

Perceived Fatigue: Significant ($p<0.001$) differences in PL and total distance resulting from practice on the preceding day, were demonstrated in players who rated their level of fatigue a 1 or 2, compared to those who selected 3, 4, or 5. Significant differences in PL ($p<0.001$) and total distance ($p<0.001$) were also demonstrated in those who rated fatigue a 3 compared to those who rated fatigue a 4 or 5. Individuals who rated their perceived fatigue a 1 or 2 covered significantly ($p<0.01$) more acceleration and deceleration distance at all intensities than those who rated their fatigue as a 3. Similarly, significantly ($p<0.01$) more acceleration and deceleration distance at all intensities was accrued during the preceding practice day by those who rated their perceived fatigue a 3 when compared to those who rated it a 4 or 5 (Table 5).

Perceived Soreness: Significant ($p<0.001$) differences in total distance resulting from practice on the preceding day were demonstrated in players who rated their level of soreness a 1 or 2, compared to those who selected 3, 4, or 5, along with significant ($p<0.05$) differences in PL in those who rated perceived soreness a 1 or 2, vs. 3, vs. a 4 or 5. Significantly ($p<0.05$) more acceleration and deceleration distance was reported for all intensities for those who rated perceived soreness a 1 or 2 when compared to those who rated it a 3, 4, or 5. Additionally, significantly ($p<0.05$) less maximal-acceleration distance was covered by those who rated their level of soreness a 4 or 5 compared to those who rated it a 1 or 2, or a 3. Significantly ($p<0.001$) less low-, medium-, and high-intensity running distance was covered in those who rated perceived soreness a 3, 4, or 5 compared to individuals who rated perceived soreness a 1 or 2 (Table 5).

Perceived Sleep Quantity: Total distance was significantly ($p<0.05$) lower for those who rated their sleep quantity a 4 or 5 when compared to those who rated sleep quantity a 1, 2, or 3. Players loads were significantly ($p<0.05$) higher for individuals whose perceived sleep quantity was a 1 or 2 compared to 3, and those whose sleep quantity was a 3 compared to a 4 or 5. Significantly ($p<0.05$) greater high-intensity acceleration and deceleration distance, and max-intensity acceleration distance was reported for those who rated sleep quantity a 1 or 2 compared to those who rated it a 3, and for those who rated sleep quantity and 3 compared those whose ratings were a 4 or 5. Significantly ($p<0.05$) more max-intensity deceleration distance was demonstrated for those who rated sleep quantity a 1 or 2 compared to those rating it a 3, 4, or 5. No significant ($p<0.05$) differences in GPS and IA variables related to perceived sleep quality existed (Table 6).

Perceived Stress and Mood: No GPS and IA derived variables demonstrated significant differences when examining those who rated their stress level a 1 or 2 compared to those who rated perceived stress a 3. However, individuals who rated stress a 4 or 5 had significantly ($p<0.01$) lower PL, in addition to significantly ($p<0.01$) less total distance, low-, medium-, and high-intensity distance than those who rated perceived stress a 3. Significant ($p<0.05$) differences were reported for all intensities of acceleration and deceleration distance, with individuals who rated perceived stress a 4 or 5 covering less distance in all zones of intensity than those rating perceived stress a 3, and significantly ($p<0.05$) less high- and max-intensity deceleration distance in those who rated perceived stress a 4 or 5 compared to those whose ratings were a 1, 2, or 3 (Table 7). Individuals who rated mood a 4 or 5 accrued significantly ($p<0.05$) less PL, total distance and maxi-intensity deceleration distance than those who rated their perceived mood a 1 or 2 (Table 7).

Insert Perceived Wellness Tables 5-7 Here

DISCUSSION

The present study examined 1) the positional movement demands associated with pre-season training camp practices in NCAA division I college football players using portable GPS and IA technology and 2) assessed the daily perceived wellness associated with pre-season training camp utilizing a custom-designed questionnaire to determine if GPS-derived measures influence perceived ratings of wellness. The results of the present study confirm our hypothesis that 1) significant ($p<0.05$) differences exist in positional movement demands during pre-season training camp in NCAA division I college football players, and 2) significant ($p<0.05$) differences in GPS and IA training loads exist in the preceding day's practice for those athletes who rated their perceived wellness less favorable the following day.

The present study found significant ($p<0.05$) differences in total distance traveled between position groups within both offensive and defensive teams during pre-season training camp practice. In addition to differences in total distance covered by the WR, DB, and LB position groups, the present study demonstrated significant ($p<0.05$) differences in high-intensity and sprint distance covered by WR and DB compared to all other positions on their respective offensive or defensive teams. Similar positional differences in division I college football players participating in pre-season training camp were reported by DeMartini et. al (8). An examination (48) of division I college football players participating in competitive games demonstrated significant differences in moderate- (10.0 – 16.0 $km \cdot h^{-1}$), high-intensity (16.1 – 23.0 $km \cdot h^{-1}$), and sprint distances (> 23.0 $km \cdot h^{-1}$) when comparing WR and DB and LB to their offensive and defensive counterparts, which supports the results of the present study, requiring increased running volumes of these positions as a means of preparing for the volumes and intensities associated with pre-season camp and subsequent competitive performance. The positional differences associated with running volumes and intensities observed in the present study may be attributed to position-specific offensive and defensive requirements during training and competition. The primary responsibility of the OL group is to block defensive players, restricting them from tackling the ball carrier. Quick bursts of acceleration, deceleration, and changes of direction, frequently occurring at or near the line of scrimmage, are associated with this tactical responsibility and limit the distance traveled and the velocity achieved during each play. Similarly, players in the DT and DE position groups accelerate short distances and perform rapid change of direction movements prior to, and immediately following, physical contact with the opposing OL. Unlike their offensive and defensive counterparts who are required to travel greater distances prior to engaging an opponent, the OL, DT, and DE positions commence play approximately one meter away from their opponent, thereby limiting subsequent running distances. The differences in high-intensity distance demonstrated by the RB group compared to the OL, QB and TE groups in the present study, may be attributed to the diverse tactical requirements associated with the positional demands of the RB group, including carrying the ball, running pass routes, and blocking to provide protection for the QB on passing plays. The unique physical requirements of the LB position, including engaging OL and TE prior to tackling the ball carrier on running plays, similar to the DT and DE groups, and defending the RB, TE, and WR on passing plays, similar to DB group, are associated with specific movement profile characteristics of this position. The WR position group is required to repeatedly run routes on passing plays, serving as a primary or secondary target, and often on running plays, serving as a decoy to the opposing DB. These position-specific requirements provide explanation for the increased total, high-intensity, and sprint distance associated with the WR position. The DB position is primarily responsible for defending the WR on passing routes, in addition to providing secondary support on running plays, often requiring high-speed pursuit of the ball carrier. Consequently, the DB position is involved in repeated bouts of running, which is reflected in the present study with more total and high-intensity distance than all other defensive position groups.

An examination of the positional acceleration and deceleration distances revealed significant ($p<0.05$) differences at nearly every intensity, for the DB and LB group compared to other defensive positions. The results of the present study are consistent with the work of Wellman et. al. (48) who reported a significantly ($p<0.05$) greater number of maximal acceleration and deceleration and high-intensity acceleration efforts for the DB position group than all other defensive position groups, and significantly more for the LB group when compared to the DT and DE position group. The results of the present study, along with previous investigations (48) in NCAA division I football, highlight distinct positional movement characteristics within the defensive team. Offensively, the WR position group accumulated significantly ($p<0.05$) greater low-, medium- and high-intensity acceleration and deceleration distance than all other offensive groups. The results of the present study are supported by previous research (48) examining positional movement demands in NCAA division I football players which reported significant ($p<0.05$) differences in acceleration and deceleration efforts for the WR group compared to other offensive position groups. Collectively, these results highlight the importance of developing and implementing a well-planned training program in the weeks preceding the start of training camp, that adequately prepares athletes for the unique positional movement demands associated with pre-season practices. Currently, there is an absence of studies that have investigated the performance demands of NCAA division I football, and the movement demands associated with pre-season training camps are unknown. Accordingly, the present study provides a novel examination of performance related research in NCAA division I football that may be used by coaching and performance staff to develop position-specific training programs to optimize athlete preparation and facilitate on-field performance.

The present study provides a unique investigation of the perceived wellness associated with pre-season training camp in NCAA division I football players. Significant ($p<0.01$) differences were reported for every GPS and IA practice variables, except sprint distance, from the preceding day, distinguishing a perceived fatigue rating of 1 or 2 from a 3, and 3 from a 4 or 5. These data indicate the movement characteristics of players on a day to day basis during training camp reflect individual perceptions of fatigue, and support the integration of perceived wellness measures to manage athlete load management during training to avoid decrements in performance and compromised player development. Results of the present study are consistent with previous work (4) using a similar questionnaire in Australian rules football, which reported an increased training load on the preceding day being associated with lower wellness scores the following day during pre-season training camp. A six-week intensified training period in Rugby League players resulted in significant ($p<0.05$) increases in perceived fatigue with simultaneous significant ($p<0.05$) decreases in sprint and agility performance, that was followed by significant ($p<0.05$) improvements in both perceived fatigue and performance measures following a two-week period of reduced training (10). Examinations (30,46) of perceived fatigue following Rugby League competition reported significantly ($p<0.05$) less favorable fatigue scores accompanied by significant ($p<0.05$) reductions in neuromuscular performance, with perceptions of fatigue and soreness outlasting reductions in performance measures. In Australian footballers, Gallo et. al (12), reported that pre-training ratings of perceived wellness significantly impacted PL during the subsequent practice session. Although the present study did not examine the impact of perceived fatigue on subsequent practice variables, unfavorable ratings of perceived fatigue may potentially alter exercise tolerance, thereby reducing the quality of practice on the same day. The results of the present study confirm those of previous investigations (4,30,46) highlighting the importance of quantifying and managing the external training load in addition to the perceived fatigue of NCAA division I football players, particularly during and immediately following pre-season training camp. Employing subjective wellness questionnaires similar to the one utilized in the present study, appears to be an effective means of monitoring the internal response to pre-season training camp practices in college football players. Members of the performance staff should work in a collaborative manner with the goal of increasing the physical fitness, supporting the improvement of tactical and technical requirements, and mitigating the risk of undesirable outcomes which may include increased injury risk associated with increased feelings of fatigue (26), illness, and poor performance during pre-season training camp in NCAA division I football players.

Significant ($p<0.001$) differences in total, low-, medium-, and high-intensity running and acceleration and deceleration distance at all intensities were demonstrated between individuals who rated their level of perceived soreness a 1 or 2 and those who rated it a 3, 4, or 5. Significant ($p<0.05$) differences in PL distinguished soreness ratings of 1 or 2 from a 3, and a 3 from a 4 or 5. Examinations in Australian footballers (4) have also demonstrated daily variations in external load associated with pre-season training camp have a significant ($p<0.001$) impact on wellness measures, including soreness, fatigue, sleep quality, stress levels and mood the following day. The present study examined the effect of practice loads on perceived wellness the following day, however, muscle soreness may persist for longer periods following fast velocity eccentric muscle contractions that are characteristic of participation in contact team sports like college football (35). Although biochemical markers of soreness were beyond the scope of this study, significant ($p<0.05$) elevations in creatine kinase have been demonstrated in division I college football players following 4 and 7 days of pre-season training camp (9), likely resulting from the blunt force trauma and eccentric muscle actions associated with collisions and stretch shortening cycle exercise inherit to participation in contact team sports (32). Soreness following intense team sport exercise may be expected, however, clear guidelines do not exist as to what alterations, if any, in training load should be made in response to differing levels of soreness (25). Collectively, the performance team should examine the practice loads of athletes who report persistent soreness to determine if the soreness is an intended consequence of properly programmed loads or an unexpected result of excessive loading, and take appropriate measures, including the modification of subsequent training sessions to reduce the likelihood of cumulative fatigue and performance decrements.

No significant ($p<0.05$) differences in GPS and IA variables were reported relating to perceived sleep quality, however significantly ($p<0.05$) less running distance and acceleration and deceleration distance at all intensities were demonstrated for individuals rating perceived sleep quantity a 4 of 5 vs. a 1, 2, or 3. Additionally, significant ($p<0.05$) differences in GPS variables, including PL, high-intensity acceleration and deceleration distance, and max-intensity acceleration distance were able to distinguish a rating of a 1 or 2 from a 3 and a 3 from a 4 or 5. The findings of the present study are consistent with those of Hausswirth et. al. (14) who reported reductions in sleep quantity associated with overreached athletes participating in intense training. In German Football League players, less favorable ratings of perceived sleep were associated with a significantly ($p=0.01$) higher subsequent risk of injury, indicating that a lack of sleep, or non-refreshing sleep increases injury risk (26). It is reasonable to suggest the reductions in sleep quantity observed in the present study may be attributed to the increased practice loads and the fatigue or muscle soreness associated with those loads (14). Libert et. al. (27) reported decreases in sleep quantity associated with exposure to heat before and during sleep, and as such, it is plausible to suggest that other factors including ambient environmental temperature, which were not controlled for in the present study, may potentially impact sleep. The results of the present study emphasize the importance of individualized athlete monitoring strategies, including perceived measures of sleep quantity, by those seeking to maximize on-field performance and mitigate the deleterious effects of fatigue associated with intense training.

Individuals who responded more favorably, indicated by a rating of a 4 or 5 for the subscale of perceived stress, demonstrated significantly ($p<0.05$) less PL, total, low-, medium-, and high-intensity running distance and acceleration and deceleration distance at all intensities, in the preceding practice session than those who rated perceived stress a 3. However, significant ($p<0.05$) differences were not established between those who rated stress a 4 or 5 compared to those who rated stress a 1 or 2 for many movement variables, which may be explained by the limited classification of unfavorable ratings for this particular subscale, thus skewing responses toward the normal or more favorable direction. Previous work (4) in Australian footballers has reported that an increase in daily training load associated with a pre-season training camp negatively impacted perceived stress the following day. Similarly, Rugby League players demonstrated increased stress and decreased recovery during an intensified training period (5) supporting the utility of monitoring the individual stress response associated with participating in contact team sports. The findings of the present study and previous examinations in contact team sports (4,5) support the utility of monitoring the individual stress response associated with participating. Previous research (42) has indicated the subscale of emotional stress may provide limited utility for monitoring athlete well-being, while non-training stress has been identified as potentially useful in monitoring acute changes in wellness. The present study did not differentiate between the potential sources of stress, but rather identified stress as a global gestalt measure. In division I college football players, both physical and psychological stress have been positively associated with injury occurrence (29,36), and as such, the inclusion of the stress subscale as part of the daily monitoring of athlete wellness may be advantageous in decreasing the likelihood of maladaptation resulting from all sources of stress associated with participation in division I college football.

The results of the present study provide novel insight into the position-specific movement demands of NCAA division I pre-season training camp and provide sport and performance coaches with quantified information, which may be used to optimally prepare football players for this intense period of physical training. The present study demonstrated sizeable differences in the positional movement demands of division I football players participating in pre-season camp, highlighting the importance of position-specific training programs to adequately address the physical demands associated with this period of training. In addition, the present study is the first to report the perceived wellness in NCAA division I football players following pre-season training camp practices. Substantial differences in volumes and intensities of GPS and IA movement variables were reported in athletes who responded more or less favorably on perceived wellness subscales. The use of wellness questionnaires may provide sport coaches and performance managers an increased understanding of the training response associated with pre-season training camp practice loads, and provide increased certainty when programming and adjusting the individual training load prescription in pre-season training camp. The ease of administration and cost effectiveness associated with monitoring the athlete training response through subjective means allows football teams, at all levels, to implement these strategies throughout the competitive season without the need for a significant time or monetary investment.

PRACTICAL APPLICATIONS

Data from the present study increase our understanding of the physical movement demands of pre-season training camp in division I college football players, and provide scope for the design of position-specific training strategies for coaches seeking to optimize training for the demands of pre-season practice. A better understanding of the demands of positional movement demands and perceived wellness associated with pre-season training camp in NCAA division I football players is required to improve the analysis of individual performance characteristics and implement a systematic approach to the development of position-specific training programs. The results of the present study indicate considerable positional differences exist with respect to movement demands and perceived wellness scores during pre-season training camp in NCAA division I football players. Performance coaches should administer position-specific training programs during the summer conditioning period that adequately prepare players for the physical demands of pre-season camp. Specifically, an appropriate volume of total, high-intensity, and sprint distance, in addition to acceleration and deceleration distance should be undertaken prior to pre-season training camp.

The present study also provided a novel analysis of the physiological and psychological response to exercise loads associated with practice on the preceding day. These data support the use of daily perceived measures of wellness to quantify the internal response to practice loads in division I football players participating in pre-season training camp. Subjective measures of perceived wellness, including fatigue, soreness, sleep quantity, and stress appear to be sensitive to differences in training load from the preceding practice day in NCAA division I football players, and may be used to monitor the adaptive response to pre-season training camp practices. It is up to coaches and performance staff to determine if unfavorable wellness scores are an intended consequence of participation in pre-season practices or an unintended result of improper practice volumes and intensities. Minimizing the deleterious effects of fatigue while simultaneously improving the position-specific technical, tactical, and physical demands associated with athlete preparation in division I college football players requires a collaborative effort between members of the coaching staff, medical staff, performance staff, and most importantly, the athletes themselves. The ease of administration, cost-effectiveness, and the minimal time investment required to collect perceived wellness data, makes it a practical tool for monitoring team sport athletes.

Data obtained from the present study provide a better understanding of the movement demands and the resultant physiological and psychological responses of NCAA division I football players to pre-season training camp. This information provides a foundation from which to implement a systematic approach to the development of individual and position-specific training programs that adequately prepare athletes for the rigors of this period of time. Future investigations should examine the impact of perceived wellness scores on performance and injury risk.

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