Neuromuscular Performance:

The Countermovement Jump and Its Relationship to Sleep, Recovery, and Psychological Factors in Male Collegiate Basketball Athletes

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by
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ABSTRACT

Neuromuscular performance (NMP) can be regarded as the ability of the neuromuscular system to functionally control and drive movements by an appropriate integration, coordination and use of sensory feedback, reflex activity, central motor drive, muscle recruitment pattern, muscular excitation-contraction coupling and energy substrate availability. More simply stated, neuromuscular performance relates to the synergistic relationship between coordination and force application. It is associated with underpinning biomotor abilities (e.g., sprinting, jumping, and change of direction) necessary for sport participation. The ability to measure and monitor NMP may provide medical and performance-related professionals the ability to glean greater understanding regarding the readiness of athletes as they navigate the training process and competitions.

The countermovement jump (CMJ) has emerged as a valid and reliable monitoring tool in applied and laboratory settings with extensive research investing the utility of the CMJ in field and court-based sports like soccer, rugby, and basketball specifically. Despite the wealth of evidence investigating the CMJ and its dose-response to training constructs like external load and disparate methodological training protocols, there is a paucity of literature investigating other ecological factors surrounding participation in sport and their relationships to neuromuscular readiness. The purpose of this dissertation was to investigate the effects of sleep, recovery modality, and psychological stress on NMP in division I male basketball student-athletes.

The purpose of manuscript 1 was to evaluate the effects of sleep duration on NMP performance and shooting accuracy in a shooting task constructed by a sport coach specific to the technical and tactical demands of collegiate division I basketball during the preseason. We did this using an observational prospective cross-sectional design using best and worst night sleep

weekly to evaluate differences in select CMJ variables, shot percentage, and wellness while controlling for accelerometry derived external training load. We found that there were significant differences in best and worst night sleep in our study cohort. However, we did not observe significant differences in CMJ variables, Jump Height (JH) and Flight Time:Contraction Time (FT:CT) as well as shooting accuracy, or wellness measures across the 3 weeks of the preseason.

The purpose of manuscript 2 was to evaluate the effects of recovery modality on NMP during the early competitive season in collegiate basketball. We used an observational prospective, randomized block-controlled design to evaluate the differential effects of flotation-restricted environmental stimulus therapy (Floatation-REST), peristaltic compression therapy (PPDC), and a control treatment on select CMJ variables and wellness measures 16-20 hours post recovery treatment during 3 weeks of the early inseason in collegiate basketball players. Our results showed no statistically significant differences in CMJ variables JH, FT:CT and countermovement depth (CMD) pre to post across recovery interventions. Additionally, we observed no significant differences in wellness measured via the Short Recovery Stress Scale (SRSS) between Floatation-REST, PPDC, or Control treatments.

The purpose of manuscript 3 was to evaluate the effects of psychological stress on NMP during the competitive season in collegiate basketball. We used an observational prospective, repeated measures design to investigate the effects of psychological stress measured via the CCAPS-34 to detect domain specific (e.g., depression, general anxiety, social anxiety, academic stress, eating concerns, frustration/anger, and alcohol use) over the course of the late in-season in collegiate basketball. Our resulted showed that there were statistically significant reductions in neuromuscular performance during the season. We observed statistically significant decreases in JH and Modified Reactive Strength Index (RSI-Mod) across the late inseason. Our investigation revealed that differences in CCAPS-34 subscales across the study did not rise to the level of significance, however, we did see trends that suggest the CCAPS-34 instrument is sensitive to period of increased academic demand. Contextually, our data revealed that significant reductions in NMP did correspond with non-significant, yet meaningful increases in academic stress, game congestion, and increased travel. Interesting, our secondary analysis comparing PlayStatus did not reveal differences in NMP or CCAPS-34 measures.

In undertaking these studies, the challenges of in-situ research were demonstrated. Small sample sizes in isolated team settings challenge the use of inferential statistical models. There is a need to for collaboration across multiple teams to construct larger datasets for analysis. Despite these statistical obstacles we were able to observe trends that may elucidate practically significant findings that may aid practitioners who a required to make informed decisions based on observations in NMP and interactions with sleep, recovery modalities, and psychological factors in real world settings.

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APPROVAL OF DISSERTATION

This dissertation, "Neuromuscular Performance: The Countermovement Jump and Its Relationship to Sleep, Recovery, and Psychological Factors in Male Collegiate Basketball Athletes", has been approved by the Graduate Faculty of Education and Human Development in partial fulfillment of the requirement for the degree of Doctor of Philosophy.

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product of my effort to be a **servant** and show up for a group of young men who hope to reach the highest levels of competition and eventually play a silly game in hopes of providing for themselves and their families. Most importantly, one can only complete this process if they have **passion** and a persistence for answering questions that may help answer questions that may allow people to reach dreams and hopefully improve their quality of life. And most importantly being **thankful** for the opportunity to "fail better" that is presented each day of this type of journey.

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THE EFFECTS OF SLEEP DURATION ON NEUROMUSCULAR PERFORMANCE, SHOT ACCURACY, AND WELLNESS MEASURES IN COLLEGIATE BASKETBALL ATHLETES

ABSTRACT

Background: Sleep has been found to be a critical factor in physical and mental well-being broadly. There is limited research investigating the effects of sleep duration on neuromuscular performance in collegiate athletics. Moreover, there is even less research exploring the effects of sleep duration on neuromuscular performance, accuracy of a sporting skill, and perceived wellness simultaneously. Observing the effects of sleep duration on neuromuscular capacity, a sport-specific task, and perceived well-being may be of great value to medical, performance, and technical staff in understanding the sleep habits and patterns in collegiate basketball student-athletes and the subsequent effects on performance related variables. The purpose of this study was to investigate differences in sleep duration across a NCAA D1 collegiate basketball team and its effects on performance in countermovement jump (CMJ), a shooting task battery, and wellness scores in the short recovery stress scale (SRSS).

Study Design: Longitudinal, prospective, observational cohort study

Methods: Data from 12 male collegiate basketball athletes (mean ± SD; age, 20.5 ± 1.98yrs; height, 198.2 ± 10.04cm; body mass 95.83 ± 11.72kg) playing for the same team during the 2022-2023 NCAA basketball season were analyzed over 12 training sessions. CMJs, a position specific shooting task, and wellness measures were performed 3 times per week over the course of the 3-week pre-season to assess CMJ variables (JH, FT:CT, CMD) of interest and overall shooting percentage in conditions of best and worst night sleep duration. Additionally, accelerometry-derived training load (PL) was included as a covariate to account for sports-related stress at each week to account for external training load.

Results: A paired samples t-test revealed a significant difference between best (M = 475.00 SD ± 40.45 min) and worst (M = 380.34 ± SD 70.93 min) night sleep duration. Best sleep duration was 94.82 minutes greater than worst sleep duration (t)(11) = 5.99, p < .001, 95% CI [60.03, 129.61] Cohen's d = 1.73 95% CI [.801, .2.628). MANCOVA revealed no significant effect for each week of the study and was eliminated from the final analysis. For the neuromuscular performance, shooting accuracy, or perceived wellness measures, a 2x3 repeated measures MANOVA revealed no significant main effect between sleep conditions, F(4,8) = 2.818, p = .099, partial η^2 = .59); no significant main effect across time, F(8,40) = 1.196, p = .326, partial η^2 = .19); and no significant interaction for sleep condition*time, F(8,40) = 1.558, p = .168, partial η^2 = .24).

Conclusions: In this cohort of NCAA D1 basketball student-athletes, sleep duration did not have negative effects on neuromuscular performance, shooting accuracy, or perceived wellness across the pre-season.

KEYWORDS: Athlete Monitoring, Sleep, Basketball, Countermovement Jump, Wellness

INTRODUCTION

There are well established benefits to sleep related to longevity and health span. In general, the body of research on sleep suggests that it has associated beneficial effects on cognition, mood, disease risk and athletic performance [1–4] amongst others benefits. Conversely, the literature has also associated negative impacts on physical and mental performance and injury risk with sleep below 7-8 hours in athlete populations.[5] The current literature recommends 7-10 hours of sleep per night stratified by age groups for teens and adults.[4,6] Sleep research in sport has also been investigated and there is a strong push in the sports science community to increase studies on its effects on performance. Most of the research on sleep is generalized to non-athlete populations. There is a need for greater understanding into the sleep demands of athletes and how the specific ecological constraints and challenges in sport shape sleep norms and their effects on performance in this population. Sleep has been researched across multiple sports related to performance with significant findings related to its effects related to long distance travel and crossing time zones. [7,8] Despite this body of research, previous studies have not yet considered all the confounding factors in real world settings. More research is warranted investigating differences that may exist between athletic levels (e.g., collegiate, professional, etc.) and type of sport as there are commonly differences in time demands, responsibilities, and constraints for each that ultimately impact sleep.[9]

In sport, competitive outcomes are predicated on the ability of the athlete to use bio-motor abilities (e.g., walking, sprinting, jumping, etc.) to problem solve movement tasks and position themselves for the expression of a sporting skill. Neuromuscular status, or current neuromuscular abilities, can be associated with underpinning physiological factors that contribute to an athlete's capacity to produce muscular mechanical force [10] and subsequently the production of muscular force for the expression of locomotor and sports-specific task execution. Jump testing utilizing force plates has commonly been used to assess and monitor neuromuscular performance parallel to training and fatigue-related responses in athletes with a varying range of neuromuscular changes noted in conditions of fatigue.[11] The countermovement jump (CMJ) specifically, has emerged as a valid and reliable measure of neuromuscular performance (NMP).[12–14] The CMJ has also been associated with the aforementioned bio-motor tasks [15,16] necessary for sport. Its practicality has allowed it to emerge as an athlete monitoring tool for evaluation of NMP, specifically in collegiate and professional basketball.[14,17–19]

Associations between sleep and basketball performance related outcomes have previously been investigated. Subjective sleep extension has been shown to have beneficial effects on free throw shooting percentage and sprinting times in male college basketball athletes.[20] The advent of new wearable technologies allows for more objective and accurate data collection of sleep via of athletes "*in situ*". The effects of sleep with-in the context of ecological constraints and demands of a NCAA collegiate athlete have not been well investigated beyond the seminal work of Mah et al., 2011. More research is warranted regarding quantitative analysis of sleep in the practical setting, moving beyond common techniques of subjective measures of sleep through self-reported survey measures. [9]

Athlete monitoring has long utilized wellness surveys to gain insights into perceived health and mental well-being of athletes. Previous research has supported the use of these measures but there are concerns that previous proxy measures promote conceptual ambiguity and compromise understanding of the components of athlete well-being.[21,22] Subjective well-being measures are obtained through self-report methods, which leave many instruments subject to bias based on how questions are phrased and subsequently interpreted.[23] Many of the instruments and questions utilized in these surveys have not been validated for use in athlete populations. The need for an ecologically validated instrument is warranted to account for the specific demands and environmental factors associated with team and individual sport participation. To date, only one survey instrument, the Acute Recovery (ARSS) and Stress Scale and Short Recovery and Stress Scale (SRSS) has been thoroughly vetted for use across disparate sports and languages.[24]

The complexity of interactions between sleep, external training load (TL) and perceptual wellness surrounding athlete readiness and performance is daunting for sports scientists and coaches to comprehend. Understanding the multi-factorial nature of physiological, technical, and tactical performance in isolation does not allow practitioners to best create training environments, interventions, and periodization approaches to promote improved outcomes.

Therefore, the purpose of this study was to investigate the effects of sleep duration on neuromuscular performance, shooting accuracy, and self-reported wellness during the pre-season training phase in male collegiate basketball players. Specifically, the present study explored the differences in select CMJ variables Jump Height (JH) and Flight Time: Contraction Time (FT:CT), shooting accuracy in a position-specific shooting task, and wellness measured by the validated short recovery stress scale (SRSS) following "best" and "worst" night sleep across a 3-week training phase while controlling for external training load via accelerometry. We hypothesized that following "worst" night sleep durations there would be decreases in JH, FT:CT, shot accuracy, and self-reported wellness compared to measures following “best” night sleep duration.

METHODS

Study Design

An observational repeated measures study design was used to evaluate sleep duration and changes in neuromuscular performance, shot accuracy, and wellness measures over the course of a 3-week pre-season training phase. Three CMJ kinetic dependent variables were selected as measures of NMP (JH, FT:CT, CMD) while percentage of made shots was selected as a measure of accuracy in a novel shooting task developed by the coaching staff specific to the positional, technical, and tactical demands of the team. The independent variables were time (week at 3 levels) and condition (best and worst night’s sleep duration).

Participants

Data were collected from 12 male collegiate basketball players (20.6 ± 1.94yrs; age; 198.2 ± 10.4cm; 95.83 ± 11.72kg) from a single National Collegiate Athletic Association (NCAA) Division I Team during the pre-season. The team roster included 14 members, however, only 12 members were included due to logistical constraints and limited access to athlete monitoring technology. The study protocol was approved by the university’s institutional review board (IRB Protocol #4812). Due to the practical setting in which measures were collected and the retrospective nature of data analysis, the University of Virginia IRB determined that participants were not required to provide informed consent.

Study Timeline

For the purposes of the study the pre-season is defined as the period of time ranging from the start of the fall academic semester until the start of NCAA sanctioned practice (e.g., late August to late September). During the study timeline, participants completed a total of 3 CMJ assessments, shooting accuracy tasks, and wellness surveys per week over the 4-week preseason. For the purposes of this study Week 1 was considered an acclimatization period for the shooting task as participants were entering the study with true rest and no structured team training exposures (practices) were scheduled. We will refer to week 1 as week zero and hence data were analyzed for the remaining weeks (1-3) for this study. Participants completed the SRSS upon arrival to the facility, performed a standardized warm-up, completed the CMJ assessment and then proceeded to the shooting task. Data collection took place on Monday, Wednesday, and Friday at the same time of day during the 4-week pre-season. Participants wore IMU devices (Catapult S7, Brisbane, Australia) during all on-court basketball activities to quantify external training load (TL) across the training weeks.

Instrumentation

Sleep data were recorded using the consumer grade Oura Ring (Generation 3, Oulu, Finland). The Oura ring is a commercial grade sleep tracker device that uses acceleration and gyroscope data, photoplethysmogram (PPG) signal, and body temperature to estimate sleep parameters. It has been found to exhibit 79% agreement with polysomnography and 94% accuracy for 2-stage (sleep, wake) detection.[25] The ring is lightweight (4-6 g) and has a battery life that lasts up to 1 week in regular use. The ring is connected to an Android or iOS Oura mobile application via Bluetooth. The data are automatically sent to the mobile application and then transferred to a cloud server. The data can be accessed via the mobile application or cloud server. For this study data was extracted from the cloud server via API and sent to an athlete management software (Smartabase, FusionSport, Brisbane, Australia).

Wellness measures were recorded on an iPad kiosk using the commercially available Smartabase athlete management software. The SRSS was loaded to the Smartabase platform and administered via iPad application for routine athlete monitoring and data collection. The SRSS consists of 32 adjectives which are summarized into two scales (recovery and stress). It consists of 4 question each representing physical, mental, emotional, and overall dimensions. Validation of these items were developed through exploratory and confirmatory factor analyses among different athletic populations. Based on these scales, the SRSS allows for high frequency measurements. It has been validated for use in English language and different settings.[24]

CMJ variables were selected based on previous literature.[12,26,27] Specifically, variables were selected to detect changes in output and jump strategy, kinetics that may be associated with neuromuscular fatigue.[13,28,29] CMJ variables were also selected based on their relevance to the muscular demands associated with participation in sport.[19,30–33]

CMJ data were collected using the commercially available ForceDecks FD4000 Dual Force Platforms (ForceDecks, Vald Performance, Brisbane, Australia), with a sampling rate of 500Hz. Previous literature suggests that sampling rates greater than 200hz are valid and reliable for the measurement of countermovement jump.[34] ForceDecks software (ForceDecks, Vald Performance, Brisbane, Australia) was used to analyze each CMJ. Variables of interest are listed, abbreviated, and defined in Table 1.

Shot accuracy was measured via a collection of basketball shooting tasks constructed by the coaching staff based on the technical, tactical, and positional demands of basketball and system of play of the team in which participants were sampled. This battery demonstrates face validity as it was developed by expert coaches and includes content similar to previously validated shooting task batteries.[35] Player accuracy (shots made divided by shots attempted) on the shooting battery were hand recorded by basketball staff members. Data were recorded during the shooting task and then transferred to a custom spreadsheet (Microsoft Excel, Version 16.75) for analysis. Shooting battery drills for each player position are listed in Table 2.

External training load (eTL) data were collected via the Catapult Sports Vector S7 IMU (Catapult Innovations, Melbourne, VIC, Australia) comprised of a triaxial accelerometer, gyroscope, and magnetometer, sampling at a rate of 100Hz which allowed for the quantification of PlayerLoad™ [36] during indoor activities. Participants wore the same micro-sensor units on their back (between the scapulae) in a fitted garment for each on-court practice session.[37]

Data Collection

Sleep

Participants were instructed to wear the Oura Ring (generation 3) while sleeping on the nights prior to data collection. Participants were not required to wear the ring outside of sleeping hours and data for this study was only collected on Sunday, Tuesday, and Thursday night's sleep in an effort to reduce athlete monitoring burden on the student-athletes. Participants were fitted for rings using a sizing kit provided by Oura Ring (Oura Health Ltd, Oulu, Finland) for the preferred ring. Participants were instructed to choose the finger and size of choice as long as the sensors on the ring were in contact with the skin of the selected finger. Upon waking athletes were instructed to open the Oura application on their mobile phones and sync ring data to the Oura Cloud. Upon download the data was visible and available for the athlete to review but they were instructed to not view data before reporting

Wellness measures. Additionally, the data was forwarded from the cloud to an athlete management platform (Smartabase, Fusion Sport, Queensland, Australia) for data aggregation and analysis.

Wellness Measures

The SRSS was utilized to measure perceived wellness upon entering the strength and conditioning center. Participants were also asked to record the number of hours slept the previous night, rate overall muscle soreness on a scale of 0-10 (o-no soreness, 10-maxial soreness), and use a body diagram to select and rate specific areas of soreness. Perceived sleep and overall soreness and use of the body diagram were collected as a part normal routine athlete monitoring but were not analyzed in this study. These wellness measures were presented 3 times per week on a tablet device (Monday, Wednesday, and Friday) in the performance center before the start of warm-up for the CMJ data collection.

Countermovement Jump Assessment

CMJ assessments were performed at the performance center, which is directly adjacent to the practice court, on Monday, Wednesday, and Friday mornings. Participants performed a standardized warm up prior to each testing session, which included dynamic stretching and locomotion patterns (e.g., skipping, jogging, and running) which progressed in intensity over the course of the warm-up to prepare participants for maximal jump performance during the CMJ assessments.[17] To perform the CMJ, athletes started in the tall standing position, with feet placed hip width to shoulder width apart and hands akimbo. The participant was then instructed to start with equal weight distribution on both force cells. A visual representation of vertical force and weight distribution was displayed on a monitor in front of the participant to provide synchronized and integrated feedback, allowing for the participant to adjust their positioning for equal quantities of body mass to be distributed on each force plate for the start of the jump. Once quiet stance was established the participant was then instructed to lower their center of mass to a self-selected countermovement depth, and then jump vertically "as high and fast as possible". Participants were also instructed to visualize "jumping through the ceiling" to encourage maximal vertical displacement. Finally, participants were instructed to complete the movement by landing in an athletic stance on the force platform. A "quiet stance" was acquired between jumps and the procedure was completed for a total of 3 jumps. If at any point the subject removed their hands from their hips or exhibited excessive knee flexion once airborne, the jump was ruled invalid and repeated. The ForceDecks software uses a 20N offset from the measured body mass, quantified before the jump, to define the start of movement. The average of the three jumps was moved forward for analysis.

Shooting Task

After completing CMJs participants were instructed to report to practice gym, which is equipped with 9 shooting stations. The players reported to the station aligned with the shooting task assigned to them based on position. The participants then engaged in the shooting task which last approximately 20-25 minutes. Graduate assistants and student managers hand recorded the made shots from the total 105 shots each battery consisted of. Upon completion of the shooting task the data was transferred to a customized Excel spread sheet (Microsoft Corporation, Redmond, Washington, USA) for data aggregation and then sent to the investigator for analysis and inclusion in the overall dataset.

PlayerLoad

During the study participants were instructed to wear the IMU units for the shooting task and the normal routine practice exposures conducted as part of the 8-hours per week training permitted by the NCAA during this phase of the preseason. The collection timeframe was a total of 28 consecutive days with 3 shooting tasks and 3-4 practices exposures collected per week. Within the timeframe, week 0 was deemed an acclimatization week and data was not used for analysis. During the subsequent 3 weeks of data collection for analysis there were 9 practice exposures captured for each participant. After each shooting task and practice exposure, data were downloaded and analyzed via OpenField software (Catapult Innovations, Melbourne, Australia – Version 1.22.2 Build #41409) which applies specific algorithms to transform the input of raw inertial data into standardized workload measures representative of whole-body load.[38–40] A 3-day rolling average for PL was used as a covariate in the analyses of CMJ, Shot Accuracy, and Wellness measures.

Missing Data

Missing data is not uncommon for logistical reasons in sports science studies such as equipment error or other unexpected circumstances. Participants who had modified practice exposures due to injury still had their data included for eTL but if no CMJs or shooting accuracy tests were performed on a given day, their data was imputed for analysis. Data for participants who sustained time-loss injury were not collected during their recovery period. Aberrant data identified as hardware issues were also removed from the analysis. There was one participant who failed to record sleep data in week 0. Three participants did not complete CMJs on single occasions due to injury or illness. There were 3 participants on single occasions did not complete the shoot battery due to injury or illness. One participant did not complete Wellness measures on one occasion due illness. There were two participants who missed external load data collection on single occasions due to injury or illness. In the event of missing data, imputation was utilized to complete the dataset for analysis. This constitutes 4.6 of < 5% of the of combined data for all observations.

Statistical Analysis

All data are reported as means ± SD unless stated otherwise. Statistical analyses were performed using SPSS statistical software (IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp) with an a priori significance level set at $p \leq .05$.

An interclass correlation coefficient ICC (3,k) was calculated to analyze the reliability of the shooting task and was conducted in week 0 (acclimation week).

A paired samples t-test was performed to determine whether duration of sleep for best and worst night sleep were different. Best night sleep was defined as the greatest duration of sleep over the course of a week recorded the night prior to the CMJ, Shooting Task, and Wellness measures. Worst night sleep was defined as the corresponding least amount of sleep over the course of a week. Separate one-way MANCOVAs were performed at each week to determine the effect 3-day Rolling PlayerLoad of best and worst sleep conditions on shot accuracy, and wellness variables across time (week 1, week 2, week 3). The p-value was set a priori at $p < 0.05$ for all analyses. Partial eta squared was used to assess magnitude for simple and main effects. Additionally, for pairwise comparisons Cohen's d effect sizes were calculated to interpret magnitude of difference between pairwise comparisons. Effect sizes were categorized using the following descriptors: ≤ 0.19 – trivial, 0.2-0.49 – small, > 0.5-0.79 – moderate, ≥ 0.8 – large.[41]

A repeated measures MANOVA with Bonferroni correction was also used to analyze statistically significant differences in CMJ, shot accuracy, and wellness variables across time (week 1, week 2, week 3) and between conditions (best vs. worst). The *p*-value was set a priori at $p < 0.05$ for all analyses. Partial eta squared was used to assess magnitude for simple and main effects. Additionally, for pairwise comparisons Cohen's *d* effect sizes were calculated to interpret magnitude of difference between pairwise comparisons. Effect sizes were categorized using the following descriptors: ≤ 0.19 – trivial, 0.2-0.49 – small, > 0.5-0.79 – moderate, ≥ 0.8 – large.[41]

RESULTS

Shooting Task Reliability

The results of a three measurement, absolute agreement, 2-way mixed effects model for ICC (3,1) revealed a moderate level of internal consistency, determined by a Cronbach's alpha of 0.690.[42]

Best vs. Worst Sleep

A paired samples t-test revealed a significant difference between best (M = 475 SD ± 40.45min) and worst (M = 380.34 ± SD 70.93min) night sleep duration. Best sleep duration was a statistically significant large 94.82 minutes greater than worst sleep duration (t)(11) = 5.99, $p < .001$, 95% CI [60.03, 129.61], Cohen's d = 1.73 95% CI [.801, .2.628). See Figure 1.

3-Day Rolling PlayerLoad

Week 0

There was no statistically significant difference between sleep condition on dependent variables (JH, FT:CT, ShotPercent, and Wellness) after controlling for Best Sleep 3-day rolling PlayerLoad, $F(5,5) = .735$, $p = .799$, partial $\eta^2 = .424$) or Worst Sleep 3-day rolling PlayerLoad, $F(5,5) = 1.267$, $p = .401$, partial $\eta^2 = .559$).

Week 1

There was no statistically significant difference between sleep condition on dependent variables (JH, FT:CT, ShotPercent, and Wellness) after controlling for Best Sleep 3-day rolling PlayerLoad, $F(5,5) = .135$, $p = .977$, partial $\eta^2 = .676$) or for Worst Sleep 3-day rolling PlayerLoad, $F(5,5) = .393$, $p = .836$, partial $\eta^2 = .282$).

Week 2

There was no statistically significant difference between sleep condition on dependent variables (JH, FT:CT, ShotPercent, and Wellness) after controlling for Best Sleep 3 day rolling PlayerLoad, $F(5,5) = 1.955$, $p = .240$, partial $\eta^2 = .662$) or after controlling for Worst Sleep 3 day rolling PlayerLoad, $F(5,5) = .843$, $p = .572$, partial $\eta^2 = .457$).

Week 3

There was no statistically significant difference between sleep condition on dependent variables (JH, FT:CT, ShotPercent, and Wellness) after controlling for Best Sleep 3 day rolling PlayerLoad, $F(5,5) = 2.077$, $p = .221$, partial $\eta^2 = .675$) or after controlling for Worst Sleep 3 day rolling PlayerLoad, $F(5,5) = .888$, $p = .550$, partial $\eta^2 = .470$).

Dependent Variables

Given there were no significant effects for 3-day rolling PlayerLoad as covariate on any week during this study, we removed PlayerLoad from the model and performed a 2x3 repeated measures MANOVA for our final analysis. Results are included in table 3.

We observed no significant interaction for sleep condition*time, $F(8,40) = 1.558$, $p = .168$, partial $\eta^2 = .24$) for the following variables: JH, FT:CT, Shot Accuracy, and Wellness respectively. Additionally, no main effect for sleep condition, $F(4,8) = 2.818$, $p = .099$, partial $\eta^2 = .59$) and no significant main effect for time, $F(8,40) = 1.196$, $p = .326$, partial $\eta^2 = .19$) were observed. Descriptive statistics and significance for dependent variables are summarized in Table 3 and Figures 2a-2c.

DISCUSSION

To our knowledge this is the first study to examine the effects of sleep duration on neuromuscular performance, shot accuracy, and wellness concurrently while controlling for external training load in collegiate basketball. In this study, we report data from force plates on select CMJ output and strategy-related variables, data recorded from a shooting task, as well as wellness data. We utilized sleep duration data characterized by best and worst night sleep conditions across 3 weeks of the pre-season from a wearable device. Additionally, we used IMU devices to account for eTL and its potential effects on performance. Our results were not consistent with our hypothesis that worst night's sleep duration would result in significant reductions in JH and FT:CT, shooting accuracy, and self-reported measures of wellness. These results call into question general sleep suggestions for athletic populations and negative effects on performance in general. Neuromuscular performance and expression of skill-oriented tasks in collegiate basketball players were not negatively affected by less sleep duration in this study. The main findings of this study indicate that sleep duration did not have significant negative effects on CMJ performance, shooting accuracy, or perceived wellness in this cohort of collegiate basketball athletes during the pre-season. These findings suggest that sleep duration may not inhibit an athlete's ability to express a skill or reduce vertical forces necessary to displace center of mass in conditions of decreased or worst sleep duration across a training week. These findings, however, must be considered within the context that data were from one night of impaired sleep per week and a longer timeframe may provide greater elucidation into the effects of decreased sleep on NMP and shooting accuracy.

Sleep

The results of this study showed a statistically significant 94.82 minute difference in best versus worst night sleep duration across the pre-season phase with best night sleep averaging 7.91 hours and worst averaging 6.33 hours, a 20% difference respectively. This finding shows the participants in this study were within the suggested sleep range for their age range when recording best night sleep. It also shows that worst night sleep fell below the minimum suggested threshold (7 hours) by about 10%. Overall, participants recorded a sleep duration that was similar to normally reported durations for college aged individuals.[43] This suggests that our cohort was consistent with the sleep norms of college students despite having greater daily demands related to sport participation.

Previous studies on basketball and sleep [20] encouraged athletes to extend self-reported sleep to 10 hours. Our study suggests that the demands placed on collegiate basketball players may be challenging for student-athletes to achieve sleep extension based on academic, athletic, and social demands in the academic environment specific to this study. Although not reported in this study we collected data on self-reported sleep with and observed % difference between sleep duration measured via a wearable device and self-reported perceived sleep. Further, investigation is warranted here to understand the value of monitoring sleep utilizing wearable devices. In this study we anecdotally observed a 6% difference between average self-reported (6.70 hours) and wearable recorded (7.10 hours) sleep across the entire study. This may call into question the reliability of self-reported sleep as a monitoring strategy. At this time, it is unknown if a 6% difference is clinically meaningful.

In this study we did not measure sleep quality. Sleep staging (REM, Deep, Light) has been associated with certain performance related predictors (e.g., cognition, reaction time, visual focus, etc.).[9,44] We did not measure staging in our study as sleep staging has been reported in 4-stage classification in our wearable device (Oura ring) at only 57% accuracy.[25] Hence, we opted to measure only 2-stage classification as its detection accuracy has been reported at 96% for accelerometer-based models while including temperature and HRV features.[25] Sleep quality may explain the maintenance of neuromuscular performance, shoot accuracy, and wellness in our condition of worst sleep as the shorter durations experienced on those nights may have been better quality sleep exposures and resulted in greater levels of physiological readiness. Additionally, optimal sleep duration may be specific to the individual and this cohort may have required less sleep than suggested ranges noted in the literature. We did not account for the effects of chronotypes and how a set schedule for the team may have confounding effects on group performance.

Neuromuscular Performance

There were no significant effects on neuromuscular performance associated with sleep duration in this study suggesting that collegiate basketball athletes were able to maintain the ability to maintain JH and FT:CT independent of sleep duration. Sleep deprivation, or more currently used, sleep insufficiency, refers to getting less than the needed amount of sleep[4] and is typically characterized by consecutive days of significant loss of sleep time. Previous literature has reported sleep deprivation is associated with deterioration in cognitive abilities, yet physical, well-learned, and simple psychomotor tasks show little decline in performance.[45] This may explain the maintenance of output (JH) and strategy-related (FT:CT) variables when there was decreased in sleep. Furthermore, collegiate athletes at the NCAA Division I level may be considered elite athletes. It is unclear at this time, if genetics or other biological and physiological characteristics may allow for maintenance of neuromuscular performance in conditions of decreased sleep in elite athletes.

It is important to note that despite there not being a statistically significant effect for sleep condition, Bonferroni post hoc testing did reveal a near significant, yet trivial, .20 decrease in FT:CT (p = .064, 95% CI [-0.001, 0.039], d = .18) between best and worst sleep conditions. Further evaluation, with a larger sample size may reveal more evidence specific to strategy changes and neurological down regulation that may be associated with reduced sleep. It is also possible that training adaptations to other training stress (e.g., strength training) provided for a greater capacity for force production across the weeks of this study. Future research should look to account for strength adaptations that may take place and how they may allow stability of vertical force production in despite conditions of reduced sleep.

Shooting Accuracy

We found no significant effects of sleep on shoot accuracy across the pre-season. As previously stated, sleep deprivation and insufficiency are associated with deterioration in cognitive abilities, yet physical, well-learned, and simple psychomotor tasks show little decline in performance.[45] This in addition to the adaptive response and learning effects of serial practice exposures in skill acquisition may explain why there was not a negative effect on shooting performance in the worst sleep condition.[46] Additionally, despite the shooting task being more reflective of a closed system, the neuromuscular oriented perturbations that may take place in the execution of a skill may be overcome by the high adaptability of elite athletes. Dynamical systems theory may explain an athlete's ability to express skill through acute non-linear changes to complete sporting skill successfully despite possible reductions in neuromuscular capacity,[47,48] similar to what is observed in chaotic open systems like competition play.

It is unknown at this time what implications reduced neuromuscular capacity has on the complexity of the kinematic execution of a skill-oriented task in sport. Future research should investigate that association given the current capabilities to measure on court kinematics during player movements through optical tracking systems. Our findings, without kinematic data, suggest that collegiate basketball players exhibit stability in their shooting accuracy across time despite fluctuations in neuromuscular capacity.

Limitations & Strengths

There are strengths to this study. This was an applied study conducted in a team setting which contributes to ecological validity and has practical and clinical implications as its study design may be implemented in real world settings. There are limitations to this study. We recognize, to comprehensively study the impacts of previous nights of sleep, the lag effects of consecutive nights must be accounted for in our performance outcomes. Additionally, not wearing the Oura Ring throughout the day may have limited our ability to capture napping which would have contributed to sleep extension. However, the decision was made to ease the monitoring burden placed on the athletes as we believed it potentially would be another stressor given the routine and heavily monitored environment of the participants.

Additionally, we did not investigate sleep quality which may explain higher levels of physiological readiness despite reductions in sleep duration. The length of time the data were collected was limited to the 4-week pre-season (1 week for acclimation) which decreases generalizability across different season phases. "*In-situ*" experiments in elite sport settings, such as occurred in this study, are often limited to small sample sizes which make inferential statistics difficult for interpretation and generalizability.

Considerations for Future Research

Future studies should investigate differences amongst several teams to increase the sample size. Investigation of differences among position groups, class, and across season phases is also warranted. Investigations into sex differences is also recommended to differentiate potential effects. Per our limitations we also encourage the researching staging when accelerometer-based algorithms reach greater accuracy specific to sleep staging. Additionally, the inclusion of biomarkers may provide greater insights into the mechanisms of underlying neuromuscular status as an additional study aim.

Practical Applications

Practitioners should understand sleep needs relative to environmental demands and how individual athletes tolerate fluctuations in sleep duration over the course of days, week, or months. Sleep monitoring can be a useful tool in educating athletes on their performance and dose response to external training load and other lifestyle or behavioral factors. Subsequently, strategies can be employed at the group or individual level to optimize readiness specific to sleep needs through education and behavior modification to maintain or increase performance in skill-based tasks and ensure high levels of neuromuscular readiness are maintained through a season phase.

Conclusions

The results of the present study demonstrate that sleep duration did not have negative effects on neuromuscular performance, shooting accuracy or perceived wellness in this cohort of collegiate basketball players during the pre-season.

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Table 1.1 Countermovement (CMJ) Variables and Definitions

Variable	Abbreviation	Description
Jump Height [impulse-momentum]	JH	Jump Height calculated by taking velocity at the instant of take-off and predicting the maximum vertical displacement of the Centre of Mass based on body mass (measured in centimeters). May be considered an output variable.
Flight Time: Contraction Time	FT:CT	Ratio of Flight Time to Contraction Time. May be considered a strategy-related variable.
Countermovement Depth	CMD	Minimum Displacement achieved prior to take-off. Maybe considered a strategy-related variable

Table 1.2. Technical-Tactical Based Shooting Battery Content by Position

4 Man 105	Big Man 105	Guard 105
Hook Series (2 reps of each) (from the block)	5 Hook Series (2 reps of each) (from the block)	Perimeter Action Shots
Rip Middle – Jump Stop - Finish Off 2	Rip Middle – Jump Stop - Finish Off 2	5 flat cut to corner
Rip Middle - Jump Stop - Shot Fake - Hook	Rip Middle - Jump Stop - Shot Fake - Hook	5 lift to wing
Rip Middle - Jump Stop - Shoulder Fake - Hook	Rip Middle - Jump Stop - Shoulder Fake - Hook	5 drift to corner
Rip Middle – Step-Through	Rip Middle – Step-Through	5 fill behind to top
Rip Middle - Spin Back Baseline - Finish	Rip Middle - Spin Back Baseline - Finish	5 side across the top
Repeat same series on the other side = 20 shots, 20 total	Repeat same series on the other side = 20 shots, 20 total	Repeat same series on the other side = 50 shot, 50 total
Side Ballscreen Pick and Pop Shots	Side Ballscreen and Flash Action Shots	5 side ball screen shots
6 Catch and Shoot	5 Side Ball Screen Separate (mid range)	2 pull up 2's
4 - One Dribble Pull Up	5 Side Ball Screen Separate – 1 dribble float	3 (under ball screen) 3's
Repeat same series on the other side = 20 shots, 40 total	5 Side Ball Screen (Guard Rejects) pocket floaters	Repeat on the other side = 10 shots, 60 total
MBS Pick and Pop Shots	5 Flash to Elbow Shot (from opposite block)	10 MBS shots (5 each way)
6 Catch and Shoot	5 Dunk Spot Quick Floater	2 downhill dribble pull up 2's (each way)
4 - One Dribble Pull Up	Repeat same series on the other side = 50 shots, 70 total	3 (under ball screen) 3's (each way)
Roll and Replace Shots	Middle Screen Roll Actions	10 shots, 70 total
5 Catch and Shoot	5 Short Roll/Floater Shots (from a middle screen)	5 wide curl shots (2's)
Repeat same series on the other side = 30 shots, 70 total	Repeat on the other side = 10 shots, 80 total	○ 2 catch and shoot
Guard Rejects Away-Screen Shots	Spot Shooting	○ 3 one dribble pull ups
5 Catch and Shoot	5 spots 5 shots (mid-range)	Repeat on the other side = 10 shots, 80
Repeat same series on the other side = 10 shots, 80 total	End of shooting = 5 shots, 105 total	Spot Shooting
Spot Shooting		5 shots from 5 spots — 25 shots, 105 total
5 shots from 5 spots — 25 shots, 105 total		

Table 1.3. Descriptive Statistics for Neuromuscular Performance, Shot Accuracy, and Wellness by Week

		JH		FT:CT		Shot%		Wellness	
Time	Week	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Best Sleep	Time 1	39.61	6.01	0.95	0.11	0.67	0.08	22.67	2.57
	Time 2	40.85	7.51	0.94	0.14	0.65	0.08	23.42	2.07
	Time 3	39.80	4.78	0.94	0.08	0.68	0.10	23.83	1.27
Worst Sleep	Time 1	38.90	7.28	0.92	0.10	0.66	0.06	24.00	1.81
	Time 2	41.58	6.26	0.93	0.09	0.67	0.09	23.58	1.51
	Time 3	40.81	6.66	0.93	0.10	0.67	0.09	22.50	2.11

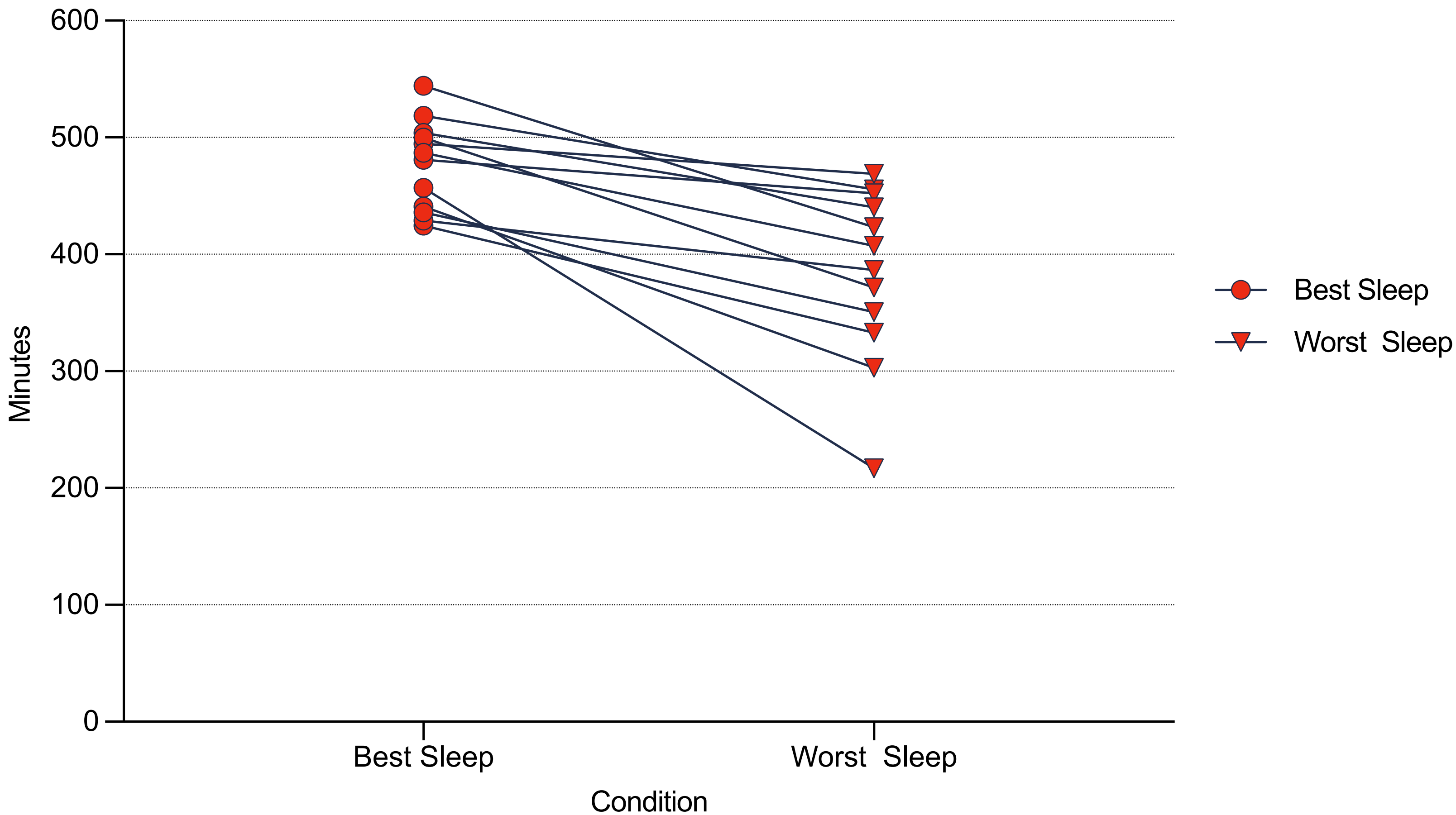

Figure 1.1. Sleep Duration by Condition.
Best (*M* = 475 *SD* ± 40.45min) vs. Worst (*M* = 380.34 ± *SD* 70.93min)

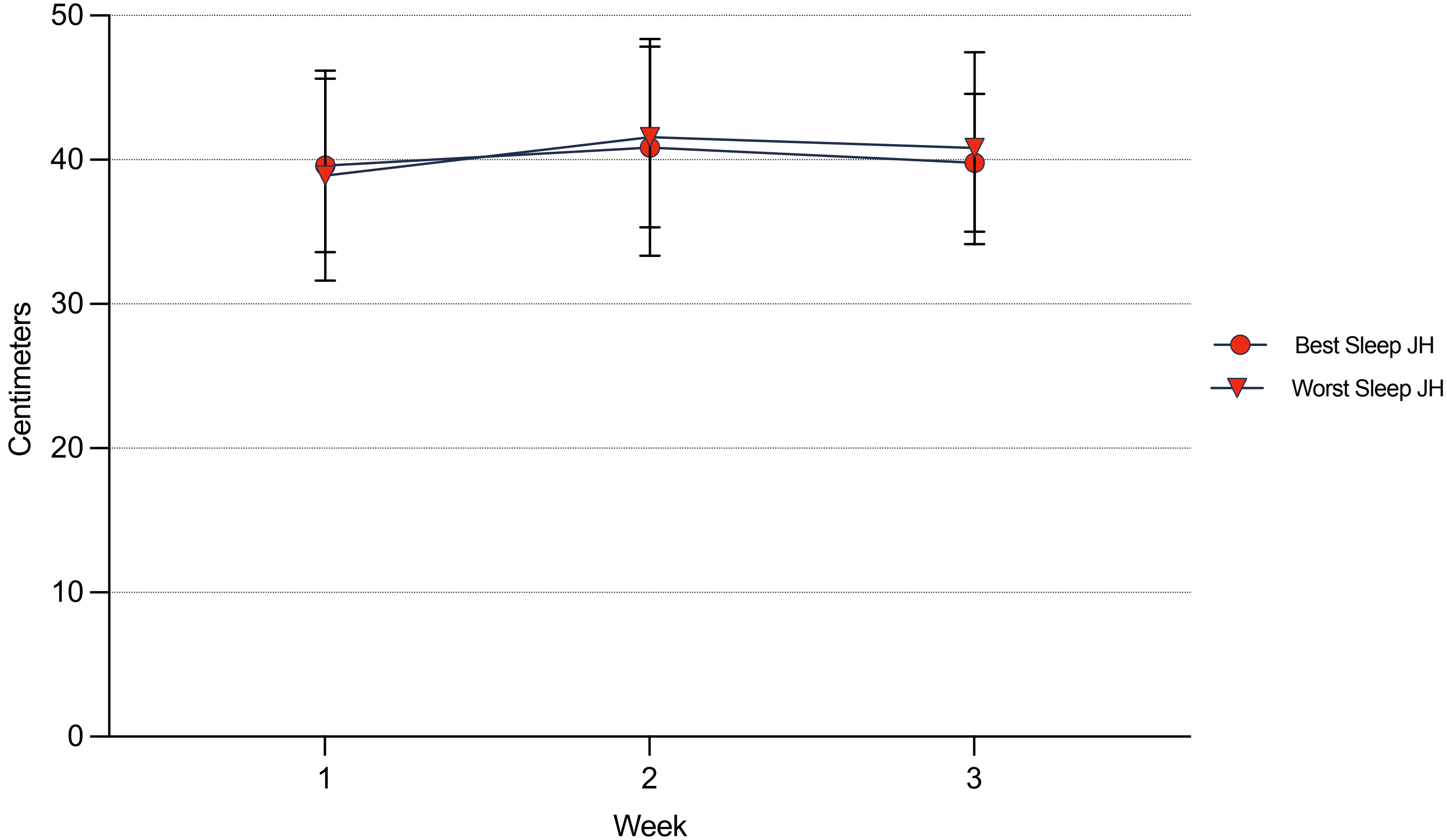

Figure 1.2a JH by Sleep Condition Across Time

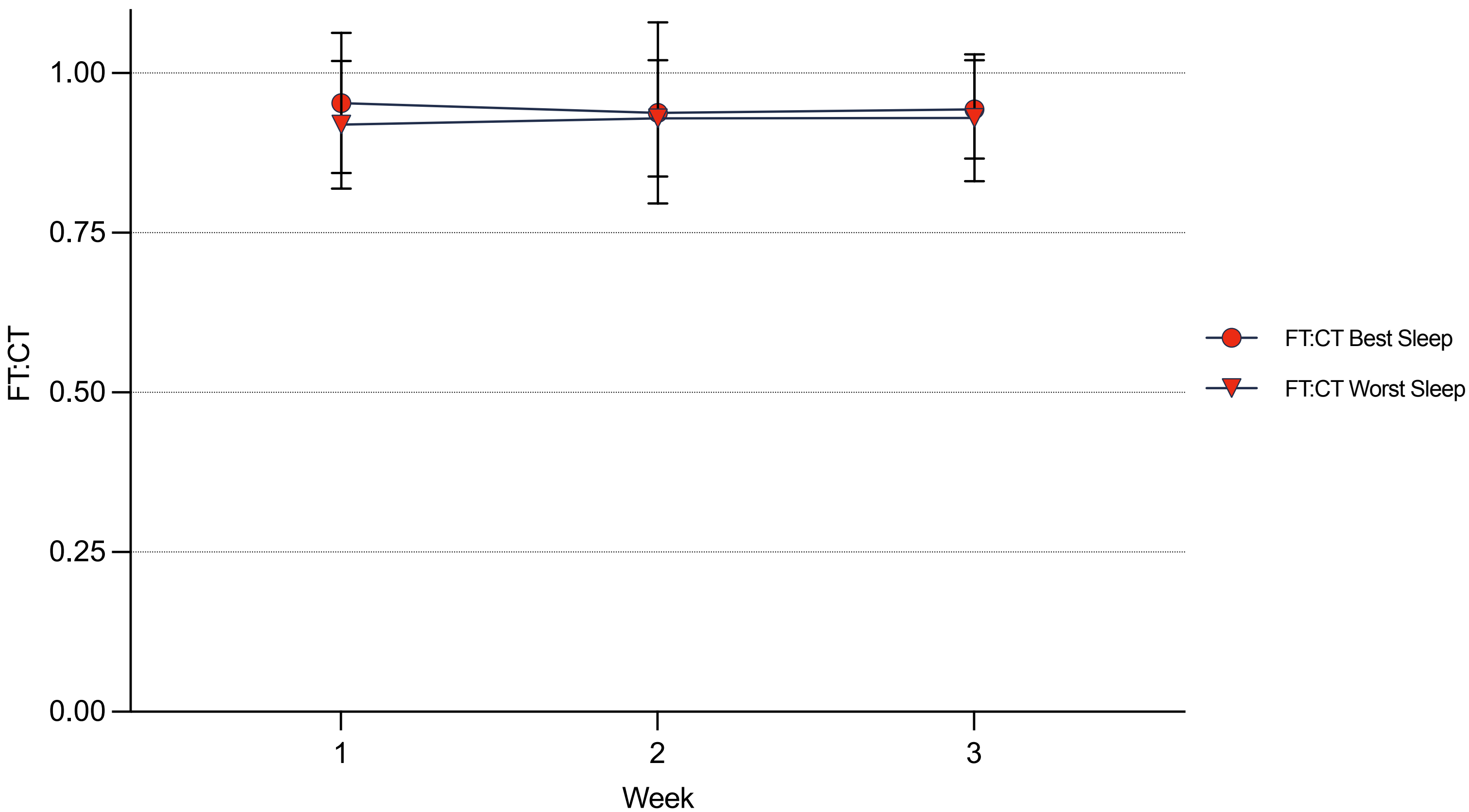

Figure 1.2b. FT:CT by Sleep Condition Across Time
Note: Data presented as Mean (Standard Deviation).

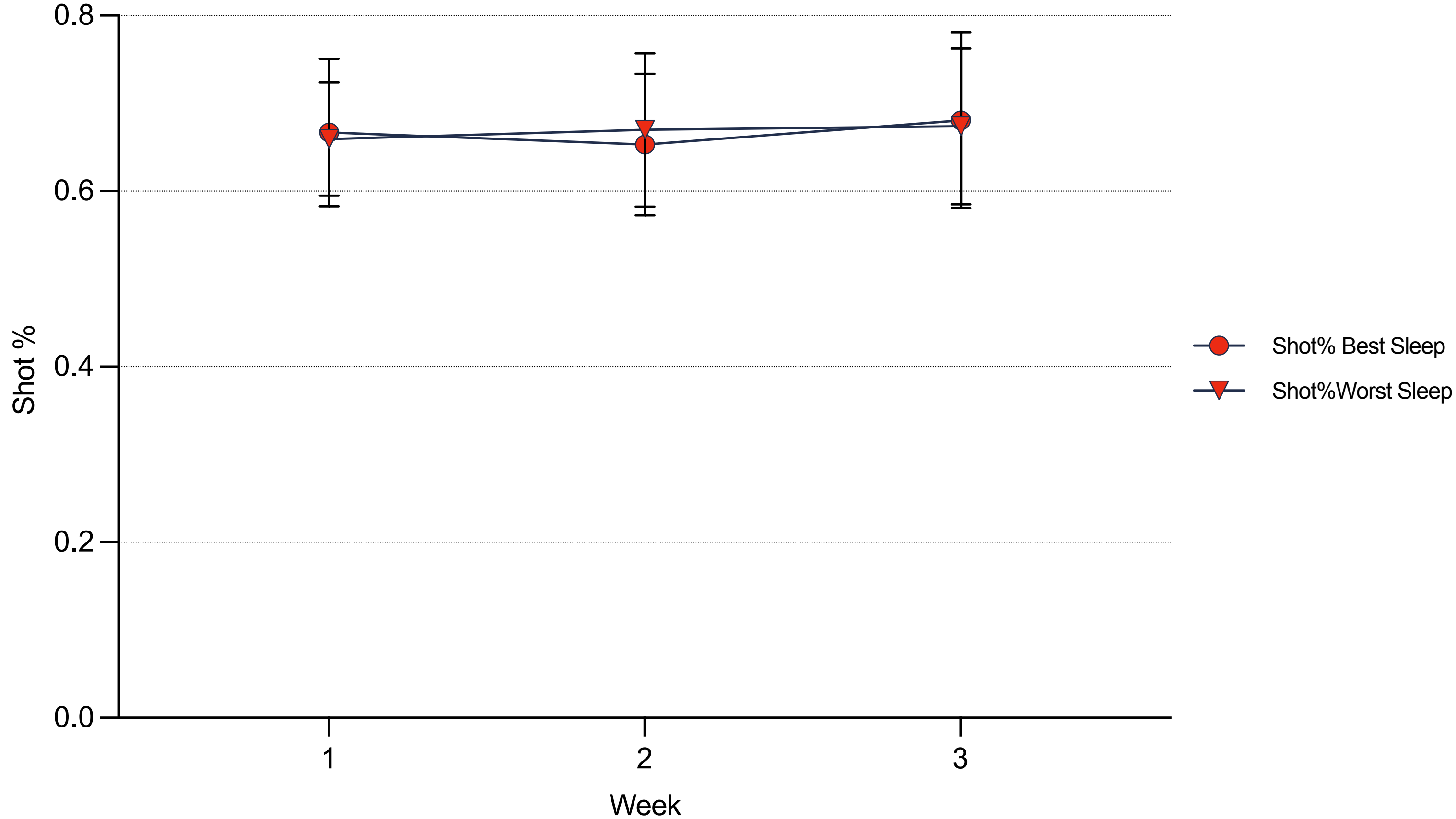

Figure 1.2c. Shot Percentage by Sleep Condition Across Time
Note: Data presented as Mean (Standard Deviation).

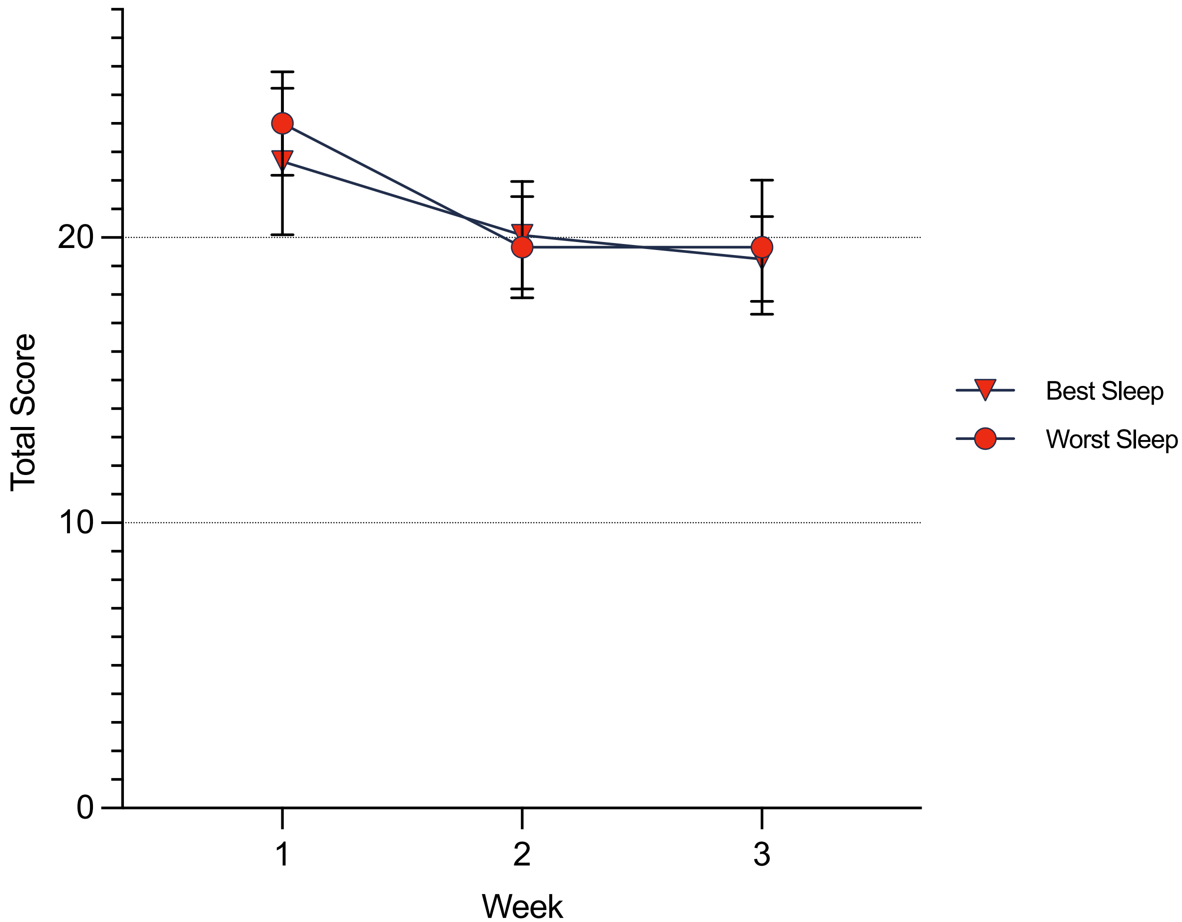

Figure 1.2d. Wellness by Sleep Condition Across Time
Note: Data presented as Mean (Standard Deviation).

SECTION II: MANUSCRIPT II

THE EFFECTS OF RECOVERY MODALITY ON NUEROMUSCULAR PERFORMANCE AND WELLNESS MEASURES IN COLLEGIATE BASKETBALL PLAYERS

ABSTRACT

Background: Recovery in sport is an emerging area of interest as clinicals and practitioners strive to optimize readiness for competition. There is a paucity of literature investigating the effects of differential recovery modalities on neuromuscular performance. Peristaltic pulse compression therapy (PPDC) has become prevalent in team and individual sporting environments. Additionally, the use of floatation restricted environmental stimuli therapy (REST) has emerged as a recovery option in many training facilities in professional and collegiate sport. Greater insights into the effects of these options are warranted to understand the magnitude of their effects on readiness physically and perceptually. The purpose of this study was to investigate the differences in effects of PPDC, flotation-REST, and control on neuromuscular performance measured via the countermovement jump (CMJ) and wellness measures in the short recovery stress scale (SRSS).

Study Design: Randomized trial with a crossover design

Methods: Data from 12 male collegiate basketball athletes (mean±SD; age, 20.92 ± 1.89yrs; height, 196.56 ± 11.14cm; body mass, 94.23 ± 12.62kg) playing for the same team during the 2022-2023 NCAA basketball season were analyzed during the early in-season. CMJ (JH, FT:CT, CMD) measures were collected 6 times, 3 pre and 3 post recovery intervention, during a 3-week period. Participants received a different recovery modality (PPCT, Flotation-REST, or Control) each week of the study and the order of modalities were randomized. Additionally, 3 self-reported wellness measures via the Short Stress Recovery Scale (SRSS) were recorded post recovery intervention for comparison between recovery modalities over the 3-week study period.

Results: A 2x3 repeated measures MANOVA revealed no significant main effect for time, $F(4,8) = 2.40$, $p = .135$, partial $\eta^2 = .55$) ; no significant main effect for recovery modality $F(8,40) = 0.58$, $p = .775$, partial $\eta^2 = .11$); and no significant interaction between time*intervention, $F(8,40) = 1.15$, $p = .356$, partial $\eta^2 = .19$) indicating there were no significant differences in the outcome measures after the administration of the different recovery modalities.

Conclusions: In this cohort of NCAA D1 basketball student-athletes, there were no significant differences in neuromuscular performance or perceived wellness between a single administration of PPCT, Flotation-REST, or a control intervention.

KEYWORDS: Athlete Monitoring, Basketball, Recovery, Countermovement Jump, Wellness

INTRODUCTION

Recovery in sport is an emerging area of interest as clinicians and practitioners strive to optimize athletes' readiness for training and competitions. An athlete's physiological and psychological capacity to recuperate from the mechanical and cognitive loads associated with practice, training, and game play may have significant implications on injury-risk, availability, and competition outcomes.[1–3] Many collegiate, professional, and national-level teams have invested in resources and modalities to aid in expediting recovery and performance enhancement.[4–6] The research into these modalities (compression therapy, sensory deprivation, etc.) is mixed as it pertains to effectiveness in sport environments, with some studies reporting attenuation of muscle soreness in resistance trained males, while others finding no significant benefits in trained cyclists and runners.[7–9] Many of the recovery modalities currently used in sports have their origins in medical and psychological-based treatments. Broadly, much of the evidence has been generalized from lay and clinical populations to justify its utilization in athletics. There is a paucity of research investigating the effects of recovery modalities '*in-situ"*, and specifically in collegiate basketball players.

Restricted Environmental Stimulation (REST) is a therapy that involves sensory deprivation and current applications involve the use of sound and light-proofed floatation tanks and suites to facilitate treatment. Previous studies have suggested Floatation-REST is effective in reducing chronic pain, stress, anxiety, muscle tension, and improvements in sleep quality in middle-aged men and women in non-athlete populations with and without diagnosed stress-related pain.[10–12] To date, there are limited studies investigating Floatation-REST as a potential recovery intervention in athlete populations. Performance outcomes in sport may be influenced by an athlete's ability to manage stressors (e.g., muscle soreness, anxiety, attentional focus, etc.) in an attempt to optimize physical and mental readiness. Flotation-REST has been found to reduce pain and improve cognitive focus in previous literature.[13] It also has been found to have beneficial effects for sleep difficulties, emotional regulation, depression, and injury risk which have emerged as areas of interest broadly in society, but also for team sport and its support units (e.g., medical, performance, sport psychology) in athletics.[14–16] Floatation-REST may have potential as a supplemental strategy in preparation for sport to reduce negative effects on neuromuscular readiness and sport performance that may be associated with mental health.[17] More research is warranted to understand effects at the group and individual level in athletic populations.

Peristaltic Pulse Dynamic Compression Therapy (PPDC) is another recovery intervention that has gained significant interest in the last 15 years. PPDC involves the application of external pressure through a series of sequential compressions and decompressions to targeted areas of the extremities. Its application as a treatment originated in the medical setting for the management of vascular health.[18] The evolution of this treatment concept has led to the production of consumer grade products. The increase in consumer availability has also led to a proliferation of use of PPDC by athletes. Research has reported enhanced flexibility and pressure to pain response in Olympic athletes.[19,20] The literature on PPDC may suggest acute modifications to mechanisms of peripheral fatigue where there are alterations in processes at or distal to the neuromuscular junction. However, despite the common use of PPDC, there is limited research to support its efficacy, and many of the findings suggest recovery benefits are short-term, transient, lack clinical meaningfulness or illicit no positive benefits.[8,21–23] The evidence related to the effects of PPDC on neuromuscular performance is also unclear as it relates to basketball players. The external nature of application in PPDC and the current literature suggest the benefits may lie in modifications to mechanisms of peripheral fatigue where there are alterations in processes at or distal to the neuromuscular junction.[24,25] Further investigation into the efficacy of PPDC is warranted in sports with high levels of tissue damage due to high volumes of eccentric contractions (e.g., deceleration, change of direction) as much of the previous research has been conducted on cyclical endurance-oriented sports.[22,26,27]

Basketball is a sport that requires high rates of acceleration, decelerations, and change of direction. These demands impose a high level of mechanical stress over the course of a training year which can lead to significant tissue level micro-trauma. The ability to facilitate neuromuscular recovery through the use recovery intervention is critical to athlete readiness and competitive outcomes. Neuromuscular status, or current neuromuscular abilities, can be associated with underpinning physiological factors that contribute to an athlete's capacity to produce muscular mechanical force and subsequently the production of muscular force for the expression of locomotor and sports-specific task execution.[28]

In basketball specifically, jump testing utilizing force plates has commonly been used to assess and monitor neuromuscular performance as well as training and fatigue-related responses in athletes with a varying range of neuromuscular changes noted in conditions of fatigue.[29] The countermovement jump (CMJ) specifically, has emerged as a valid and reliable measure of neuromuscular performance (NMP) in basketball due to its practicality.[30–32] The use of CMJ kinetic variables such as Jump Height (JH) provide practical measures of output that athletes can comprehend and associate with the demands of sport (e.g. blocking shots, rebounding, etc.), while variables such as Flight Time to Contraction Time (FT:CT) and countermovement depth (CMD) allow for insights into strategy related mechanisms for displacement of center of mass (COM) that may also signal injury or fatigue.[31,33] These CMJ measures used in routine athlete monitoring may provide insight into the effectiveness of recovery strategies used by practitioners to expedite readiness for games and training sessions.

Therefore, the purpose of this study was to evaluate the effects of recovery modality (Floatation-REST, PPCT, and Control) on NMP and perceived wellness in collegiate basketball athletes during the early in-season. We hypothesized that athletes receiving Floatation-REST will experience increased recovery and exhibit greater JH, FT:CT, and CMD measures pre to post in the CMJ compared to other recovery interventions due the global benefits associated with autonomic nervous system manipulation and modifications in both peripheral and central mechanisms of fatigue.[3] Additionally, we hypothesize that athletes will report increased measures of wellness after receiving Floatation-REST compared to PPDC and control interventions.

METHODS

Study Design

A crossover study design was used to evaluate the effects of recovery modalities on NMP and self-reported wellness measures in male collegiate basketball players during a 3-week period during the early in-season. Four CMJ kinetic dependent variables were selected as measures of NMP (JH, FT:CT, RSImod, CMD). The independent variables were time (pre to post) and recovery modality (Flotation-REST, PPDC, and Control).

Participants

Data were collected from 13 male collegiate basketball players (mean ± SD; age 20.92 ± 1.89yrs; height 196.56 ± 11.15cm; body mass 94.23 ± 12.62kg) from a single National Collegiate Athletic Association (NCAA) Division I Team during the early in-season. For the purposes this study the early in-season is defined as the period ranging from the start of the first NCAA sanctioned practice (30 exposures in 40 days, late September to Early November) to the start of the competition schedule. During this period of time student-athlete training is limited to sport coach led practice exposures and additional supportive training activities (e.g., strength training). No games are played during this season-phase. The team roster included 14 members, however, only 13 members were included due to logistical constraints and limited access to athlete monitoring technology. Participants completed a total 6 CMJ assessments (3 pre and 3 post) with pre and post measures separated by roughly 72 hours (Friday morning to Monday morning). Participants also completed a wellness survey (SRSS) upon arrival for the post-test CMJ assessment on Monday mornings 16-20 hours post recovery intervention. The use of IMU devices was also utilized during this study to account for the accumulation of external training load (eTL) across training weeks leading into pre and post-test measures. The study protocol was approved by the university's institutional review board (IRB Protocol #4812). Due to these measures being collected within the context of the teams' routine athlete monitoring procedures, the University of Virginia IRB determined that participants were not required to provide informed consent.

Instrumentation

External Training Load

External training load data during on-court basketball practices were collected via the Catapult Sports Vector T7 IMU (Catapult Innovations, Melbourne, VIC, Australia) comprised of a triaxial accelerometer, gyroscope, and magnetometer, sampling at a rate of 100Hz which allowed for the quantification of PlayerLoad.[34] Participants wore the same micro-sensors for each exposure and the units were placed on the back (between the scapulae) in a fitted garment during each practice.[35]

Neuromuscular Performance

CMJ variables were selected based on previous literature.[33,36,37] Specifically, variables were selected to detect changes in output and jump strategy, kinetics that may be associated with neuromuscular fatigue.[33,38] CMJ variables were also selected based on their relevance to the muscular demands associated with participation in sport.[39–43]

CMJ data were collected using the commercially available ForceDecks FD4000 Dual Force Platforms (ForceDecks, Vald Performance, Brisbane, Australia), with a sampling rate of 500Hz. Previous literature suggests that sampling rates greater than 200hz are valid and reliable for the measurement of countermovement jump.[44] ForceDecks software (VALD, Brisbane, Australia) was used to analyze all CMJs variables. CMJ variables of interest are listed, defined, and abbreviated in Table 1.

Recovery Modalities

All recovery treatments were administered on Sundays, a designated off day from organized basketball activities. All participants received each treatment condition over the 3 weeks of the study per the crossover design of the study. The order of interventions was administered in a randomized manner and participants were blinded to their treatment prior to arrival to the facility in week 1.

Peristaltic Pulse Dynamic Compression

Peristaltic Pulse Dynamic Compression (PPDC) treatment was administered via the Normatec Pulse 2.0 (Hyperice Incorporated, Irvine, California, USA). The Normatec is device that consists of rechargeable control unit housing a compressor to deliver air to a hose and accompanying arm, hip, or leg sleeves. The device has the capacity to compress the sleeves between 30-110mmHg of pressure and can be adjusted via the control unit. The Normatec delivers 30 second pulses per compartment inflating distal to proximal to facilitate circulation towards the heart.

During the PPDC intervention participants were instructed to wear shorts to allow for direct pressure from the leg sleeves. Treatment was only applied to the legs (right and left simultaneously). Participants were instructed to select level 6 (approx. 100mmHg) and 30 minutes in duration on the control unit, the investigator set the devices setting and started the treatment session. Thirty minutes was selected as the treatment time based on previous literature[20] and with consideration to the logistical burden placed on the student-athletes. Participants were instructed to recline in a customized anti-gravity chair or on the existing seating in the locker room (spacious couch). Upon completion of the treatment participants were allowed to leave the facility and engage in their normal daily routine but not in any basketball activities.

Floatation-REST was administered via a custom 94x78x88 inches fiberglass floatation suite (Quest Float Suite Standard Model, Superior Float Tanks, Virginia, USA) with a tank filled with approximately 1200 pounds of Epsom Salt and 300 gallons of water heated to 94-degrees Fahrenheit. The suite has the capability to be connected via Bluetooth to a mobile device for music as well as fiber-optic star ceilings to control of transitioning between LED light, starlight, or darkness.

Participants assigned to the Floatation-REST intervention were instructed to shower prior to the treatment and wear compression shorts while floating. Participants were instructed to use the darkness option and were not permitted to listen to music during the recovery intervention. The treatment time was 45 minutes and based on previous research.[10,13,23] Upon completion of the treatment participants were allowed to leave the facility and engage in their normal daily routine but not in any basketball activities.

Control

The control condition was instructed to avoid the training facility unless medical treatment was advised by the sports medicine staff. No participant was permitted to engage in a treatment modality that was used during the study. They were permitted to use hydrotherapy as a treatment modality in the form of cold or hot plunge if deemed necessary by the sports medicine staff. They were also instructed to not engage in basketball related activities on Sunday but were allowed to engage in their normal daily routine. Athletes in the control group were notified of their recovery intervention assignment at the end of all training sessions on Friday afternoon. However, due to the nature of "*in-situ*" research and collegiate basketball (e.g., recruiting visits, etc.) there fluctuations in scheduling, training sessions were scheduled on three consecutive Saturdays during the study which was not included in the original study design. In this case participants were notified after the last training session on Saturday afternoon.

Data Collection

PlayerLoad

After each practice exposure, data were analyzed via OpenField software (Catapult Innovations, Melbourne, Australia –Version Alpha Build, #78983) which applies specific algorithms to transform the input of raw inertial data into standardized workload measures representative of whole-body load.[45–47] The collection timeframe was a total of 21 consecutive days with 3 practice exposures collected per week. Within the timeframe, 9 practice exposures were captured for each participant. For analysis, the 12 practice exposures per participant were captured across 3 weeks on the early in-season. The accumulation (sum) of PL for each practice over the week was calculated and matched with pre and post-test CMJ measures as a covariate in this study. For pre-test CMJ measures the PL accumulated up to Thursday's training session was moved forward for analysis with pre-test neuromuscular measures. Any additional sum of accumulated PL accrued during a Saturday practice exposure was matched with post-test CMJ measures in the analysis. A customized Microsoft Excel spreadsheet (Microsoft Corp, Redmond, WA) was used to organize and aggregate data prior to analysis.

Countermovement Jump

CMJ assessments were performed at the strength and conditioning center prior to the strength training exposures in the mornings on Monday, Wednesday, and Friday as part of normal routine athlete monitoring over the course of 3 weeks. In week 3, data collection for pre-test measures were taken in the afternoon due to training schedule changes and logistical constraints. Post-test measures in week 3 were taken in the morning per normal routine data collection. We took additional post-test measures to account for diurnal changes with afternoon CMJ testing in week 3. A separate analysis including afternoon revealed no statistical difference between morning and afternoon observations. The afternoon post-test measures in week 3 were removed from the dataset and the morning CMJ measures were moved forward for analysis.

Participants performed a standardized warm up prior to each testing session, which included dynamic stretching and locomotion patterns (e.g., skipping, jogging, and running) which progressed in intensity over the course of the warm-up to prepare participants for maximal jump performance during the CMJ assessments.[30] To perform the CMJ, athletes started in the tall standing position, with feet placed hip width to shoulder width apart and hands akimbo. The subject was then instructed to start with equal weight distribution on both force cells. A visual representation of vertical force and weight distribution was displayed on a monitor in front of the participant to provide synchronized and integrated feedback, allowing for the participant to adjust their positioning for equal quantities of body mass to be distributed on each force plate for the start of the jump. Once quiet stance was established the participant was then instructed to lower their center of mass to a self-selected countermovement depth, and then jump vertically "as high and fast as possible". Participants were also instructed to visualize "jumping through the ceiling" to encourage maximal vertical displacement. Finally, participants were instructed to complete the movement by landing in an athletic stance on the force platform. A "quiet stance" was acquired between jumps and the procedure was completed for a total of 3 jumps. If at any point the subject removed their hands from their hips or exhibited excessive knee flexion once airborne, the jump was ruled invalid and repeated. The ForceDecks software uses a 20N offset from the measured body mass, quantified before the jump, to define the start of movement. The average of the three jumps was moved forward for analysis.

Wellness Measures

The SRSS was utilized to measure perceived wellness upon entering the strength and conditioning center. Participants were also asked to record the number of hours of slept the previous night, rate overall muscle soreness on a scale of 0-10 (o-no soreness, 10-maxial soreness), and use a body diagram to select and rate specific areas of soreness. Perceived sleep and overall soreness and use of the body diagram were collected as a part normal routine athlete monitoring but were not analyzed in this study. These wellness measures were presented 3 times over the course of the study. Participants recorded SRSS responses on a tablet device on Monday mornings in the performance center before the start of warm-up for posttest CMJ data collection.

Missing Data

Given this data was collected in-situ, missing data is not uncommon for logistical reasons such as equipment error and other circumstances. Participants who had modified practice exposures due to injury still had their data included for eTL but if no CMJs were performed their data was imputed for analysis. There was one participant who sustained an injury and was unable to perform CMJ's in week 1. Data for this participant was imputed to complete the dataset for analysis. During the study, one participant suffered an injury and opted out of the assigned recovery intervention in week 1. This in theory matched his post-test measures with our Control condition and hence his data was not imputed for pre-test measures. This reduced our sample to 12 participants as the data was eliminated from the analysis. Data in this case was not imputed into the dataset and was removed upon analysis of the dataset. This constitutes 1.7% or < 5% of the combined data for all observations.

Statistical Analysis

All data are reported as means ± SD unless stated otherwise. Statistical analyses were performed using SPSS statistical software (IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp) with an a priori significance level set at $p \leq .05$.

A repeated measures MANCOVA was performed to determine the effect of accumulated PlayerLoad of time (Pre to Post) on JH, FT:CT, and CMD across interventions. The *p*-value was set a priori at $p < 0.05$ for all analysis. Partial eta squared was used to assess magnitude for simple and main effects. Additionally, for pairwise comparisons Cohen's d effect sizes were calculated to interpret magnitude of difference between pairwise comparisons. Effect sizes were categorized using the following descriptors: ≤ 0.19 – trivial, 0.2-0.49 – small, > 0.5-0.79 – moderate, ≥ 0.8 – large.[48]

A repeated measures 2x3 MANOVA with Bonferroni correction were used to analyze statistically significant differences in JH, FT:CT, and CMD variables between time (pre to post) and across interventions (Floatation-REST, PPDC, Control). The *p*-value was set a priori at $p < 0.05$ for all analyses. Partial eta squared was used to assess magnitude for simple and main effects. Additionally, for pairwise comparisons Cohen's d effect sizes were calculated to interpret magnitude of difference between pairwise comparisons. Effect sizes were categorized using the following descriptors: ≤ 0.19 – trivial, 0.2-0.49 – small, > 0.5-0.79 – moderate, ≥ 0.8 – large.[48]

Additionally, a 1x3 repeated-measures ANOVA was conducted to determine whether there were differences in wellness scores between recovery interventions. Partial eta squared was used to assess magnitude for simple and main effects. Additionally, for pairwise comparisons Cohen's *d* effect sizes were calculated to interpret magnitude of difference between pairwise comparisons. Effect sizes were categorized using the following descriptors: ≤ 0.19 – trivial, 0.2-0.49 – small, > 0.5-0.79 – moderate, ≥ 0.8 – large.[48]

RESULTS

Accumulated PlayerLoad

Floatation-REST PRE

There was no statistically significant time*intervention effect on JH, FT:CT, or CMD after controlling for accumulated PlayerLoad. F(8,16) = .295, p = .957, partial η^2 = .129).

Floatation-REST POST

There was no statistically significant time*intervention effect on JH, FT:CT, or CMD after controlling for accumulated PlayerLoad. F(8,16) = .288, p = .960, partial η^2 = .126).

PPDC PRE

There was no statistically significant time*intervention effect on JH, FT:CT, or CMD after controlling for accumulated PlayerLoad. F(8,16) = 1 .190, p = .363, partial η^2 = .373).

PPDC POST

There was no statistically significant time*intervention effect on JH, FT:CT, or CMD after controlling for accumulated PlayerLoad. F(8,16) = .832, p = .588, partial η^2 = .294).

CONTROL PRE

There was no statistically significant time*intervention effect on JH, FT:CT, or CMD after controlling for accumulated PlayerLoad. F(8,16) = .895, p = .543, partial η^2 = .309).

CONTROL POST

There was no statistically significant time*intervention effect on JH, RSImod, or CMD after controlling for accumulated PlayerLoad. $F(8,16) = .492$, $p = .844$, partial $\eta^2 = .198$).

CMJ Variables

Given there were no significant time*intervention effects for accumulated PlayerLoad, we removed accumulated PlayerLoad from the model and performed a 2x3 repeated measures MANOVA for our final analysis.

We observed no significant interaction time*intervention effects for the following variables: JH, RSImod, and CMD, $F(8,40) = 1.15$, $p = .356$, partial $\eta^2 = .19$). Additionally, results indicated no significant main effect for time, $F(4,8) = 2.40$, $p = .135$), partial $\eta^2 = .55$) and no significant main effect for recovery modality $F(8,40) = 0.58$, $p = .775$, partial $\eta^2 = .11$). The means and standard deviations for JH, FTCT, and CMD are presented in table 2 and figures 1a-c.

Wellness

A repeated-measures ANOVA determined that mean Total Wellness scores did not differ significantly across interventions $F(4,48) = .992$, $p = .421$, partial $\eta^2 = .076$). Therefore, we can conclude that the results of the ANOVA indicate no significant effect for perceived wellness across interventions measures by the SRSS and are shown in figure 2.

DISCUSSION

To our knowledge this is the first study to examine the effects of recovery modality on neuromuscular performance while controlling for eTL in collegiate basketball. In this study we report data from force plates on selected output and strategy-related CMJ variables[33,38] and wellness scores from the SRSS.[49] We used three different recovery modalities in block randomized crossover design across 3 weeks during the early in-season phase. Additionally, we used IMU devices to account for eTL and its potential effects on recovery and neuromuscular performance. Our results were not consistent with our hypothesis and call into question the single use of PPDC or Floatation-REST as recovery modalities to modify neuromuscular performance, as assessed by CMJ, in collegiate basketball athletes. The main findings of this study indicate that there were no significant effects on CMJ performance in JH (Pre $M = 40.54$, Post M = 41.41, $p = .13$), FT:CT (Pre $M = .92$, Post $M = .93$, $p = .61$), RSImod (Pre $M = .71$, Post $M = .73$, $p = .10$), and CMD (Pre $M = -32.84$, Post $M = -33.16$, $p = .10$). These findings suggest that a single application or PPDC or Floatation-REST may be limited as tools for recovery on neuromuscular performance and the CMJ specifically in collegiate basketball players when implemented based on the typical logistical constraints observed in collegiate athletics (e.g., training and competition schedules, academic demands, NCAA rules, etc.).

Flotation-Rest

The results of this study showed no significant time*interaction effects suggesting that in collegiate basketball players a single application of Floatation-REST does not appear to meaningfully modify neuromuscular fatigue. Hence, we rejected our hypothesis that this modality would illicit greater recovery compared to PPDC or Control condition. Given the equivocal evidence up to this point specific to neuromuscular effects, our results would support the literature questioning the efficacy of sensory deprivation as a modality for neuromuscular recovery in sport. Floatation-REST has been shown to result in significant attenuation of muscle soreness immediately after treatments in athletic populations performing strength exercise.[7] Reductions in muscle soreness could be speculated to have positive impacts on peripheral fatigue (e.g., restoration of contractile capacities). However, the results of our study do not support this notion and suggest that the effects observed in previous literature may be transient and beneficial immediately post-intervention.

In addition, the association of Floatation-REST with manipulation of the autonomic nervous system suggests that Flotation-REST would have potential as an effective tool in modifying fatigue centrally and peripherally.[11,50] We did not observe any statistically beneficial results from our investigation of kinetic variables at the group level that would support this notion. We did, however, observe beneficial results in some participants suggesting that this modality may be beneficial at the individual level. Figure 1a shows a greater number of individual participants exhibiting increases in JH post-test measures compared to PPDC. It is important to note that factors like non-clinical claustrophobia or hydrophobia may limit the effectiveness of this type of intervention in some athletes and may be contra-indicated due to its potential to increase a sympathetic response.

PPDC

There were no significant time*intervention interactions observed in our study for PPDC. Furthermore, we did not observe significant differences pre to post for JH (Pre M = 41.14, Post M = 41.41, p = .63), and FT:CT (Pre M = .92 , Post M = .93, p = .47), suggesting that in collegiate basketball players, PPDC does not appear to modify neuromuscular fatigue. Although the omnibus MANOVA for all dependent measures was not statistically significant, we did observe a potentially meaningful small 1.01cm difference in CMD (Pre M = -32.68, Post M = -33.69, p = .03, Cohen's d = 0.26). This may suggest a reduction in soreness may result in a strategy change and greater negative displacement in the CMD although participants did not report improved muscular soreness scores in the SRSS. The average muscular soreness score for PPDC was 1.15 compared to 1.08 for Floatation-REST and 1.54 for the control. This suggest that Floatation-REST and PPDC did have a greater impact on participants perception of muscular stress after those treatments respectively compared to control. This increase in CMD could potentially be an example of kinematic changes consistent with previous evidence that PPDC has the potential to modify pressure to pain threshold and flexibility[19,20] in athletes after strenuous training. This also may suggest that PPDC or other active means of recovery (e.g., compression garments, electrical muscle stimulation, etc.) is best suited as a recovery modality for instances when practitioners and clinicians identify peripherally oriented fatigue mechanisms and detect alterations in movement strategies that be associated with muscle soreness.

Control

There were no significant time*intervention interactions observed in our study for the control intervention. Despite the omnibus MANOVA being non-significant, we did observe a potentially meaningful 3.21cm increase in JH (Pre M = 39.32, Post M = 42.53, p = .04, Cohen's d = 0.49) when participants experienced the control condition. Following the control intervention, participants exhibited on average a 7.5% increase in JH pre to post. JH practically, may arguably be the most important kinetic variable relative to basketball participation and understanding for the athlete. This finding suggests that in this cohort of athletes, that being away from the training facility was the best stimulus in modification of potential fatigue-related factors to neuromuscular performance 16-20 hours post-recovery intervention. In our study we hypothesized that Floatation-REST would lead to greater recovery in neuromuscular performance based on past anecdotal observation and the evidence related to autonomic nervous system responses, mood, and muscle soreness.[11,50] We believed that the downstream physiological effects related to parasympathetic reactivation and mental health would expedite neuromuscular readiness. In this cohort of athletes, avoidance of the training facility appears to have facilitated those anticipated effects.

Wellness

In this study we did not observe a significant difference in total wellness scores across interventions, suggesting that collegiate basketball players did not report wellness differences between recovery modalities and no one modality elicited greater perceptions of wellness via the SRSS. In this study we did not investigate the two scales of the SRSS independently. We did, however, observe a small increase in mean stress scale in the control condition. See figure 3. We did observe fluctuations across interventions relative to the disparate domains. We observed an average stress score of 4.3 for Floatation-REST, 3.2 mean stress score for PPDC, and 4.38 mean stress score with one potential outlier for the control intervention. This may suggest that PPDC was effective in reducing perceived stress in our cohort of collegiate basketball players. Future research should investigate differences between recovery and stress domain scores within the SRSS across recovery interventions.

In applied research, small sample sizes, in addition to a large number of dependent variables may pose challenges to interpreting clinical and practical meaningfulness of results. In our study we did not find significant time*intervention interactions for JH, FT:CT, CMD, or Wellness measures. Under-powered studies with small sample sizes have been associated with type II errors. Commonly in applied research, team roster size provides challenges to the sports scientist regarding interpretation. In our study we observed small to moderate effects without statistical significance but argue that an increase in participants may have moved to significance and increased our understanding and strengthened our conclusions. Practically, small effect sizes, milliseconds, and centimeters may have significant impacts on the proper selection of recovery modalities, game outcomes, and allocation of resources. More importantly, the data presented in this study elucidate what may be insights into precision health and the selection of the most effective recovery modality selection at the individual athlete level. We believe that the framework and findings in this study have utility in the applied setting as practitioners seek to provide effective recover options for their athletes.

Limitations & Strengths

There are strengths to this study. This was an applied study conducted in a team setting which contributes to ecological validity and has practical and clinical implications as its study design may be implemented in real world settings. This study also creates a framework to investigate responses at the individual level to recovery modality as we move towards precision health in sport.

There are also limitations to this study. We did not impose strict experimental controls (e.g., nutritional and hydration status, psychological factors, unreported injury, social and academic factors) which may have effects on neuromuscular performance and perceived wellness. The length of time the data were collected was limited to 3 weeks and single exposures to treatments in the early in-season which decreases generalizability across an entire season. The length of study limited our ability to investigate serial effects of the recovery interventions. It is possible that a novel exposure may elicit a non-repeatable dose-response in subsequent exposures. "*In-situ*" experiments in this setting are limited to small sample sizes which make inferential statistics difficult for interpretation and generalizability. Additionally, logistical constraints *in-situ* also limited our ability to use common lab-based approaches regarding pre and posttest measurements for dose-response.

Considerations for Future Research

Future studies should investigate differences amongst teams to increase the sample size. Additionally, investigation of differences among position groups, class, and across season-phases where other stressors may be accounted for. Additionally, the inclusion of biomarkers may provide greater insights into the mechanisms of underlying neuromuscular status as an additional study aim.

Practical Applications

Practitioners should seek to glean greater understanding as to the individual response of the athlete to selected recovery modalities. External means of recovery may be useful in expediting recovery in some, but not all athletes in team settings and there is utility in uncovering responders vs. non-responders. This may lead to better decisions regarding allocating resources and funding toward the most effective recovery strategies in a landscape with a multitude options.

Conclusions

The results of the present study demonstrate that the Flotation-REST and PPDC did not independently, have significant effects on enhancing recovery 16-20 hours after intervention in this cohort of collegiate basketball players during the early in-season. Although not statistically significant in this study, the findings may suggest that collegiate basketball players may benefit from facility avoidance on off days given the long duration of the competitive season NCAA D1 basketball .

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Table 2.1. Countermovement (CMJ) Variables and Definitions

Variable	Abbreviation	Description
Jump Height [impulse-momentum]	JH	Jump Height calculated by taking velocity at the instant of take-off and predicting the maximum vertical displacement of the Centre of Mass based on body mass (measured in centimeters). May be considered an output variable.
Flight Time: Contraction Time	FT:CT	Ratio of Flight Time to Contraction Time. May be considered a strategy-related variable.
Countermovement Depth	CMD	Minimum Displacement achieved prior to take-off. May be considered a strategy-related variable.

Table 2.2. Descriptive Statistics for Pre to Post JH, FT:CT, and CMD by Recovery Intervention

		JH		FT:CT		CMD	
Time	Intervention	M	SD	M	SD	M	SD
Pre	Floatation-REST	41.17	4.57	0.93	0.10	-32.43	3.15
	PPDC	41.14	6.86	0.92	0.09	-32.68	3.90
	Control	39.32	6.60	0.92	0.10	-33.42	3.86
Post	Floatation-REST	40.28	5.82	0.93	0.10	-33.17	3.50
	PPDC	41.41	5.97	0.93	0.08	-33.69	3.55
	Control	42.53	5.41	0.92	0.10	-33.54	6.04

Data presented as Mean (Standard Deviation). Abbreviations: Floatation-REST, Floatation Restricted Environmental Stimuli Therapy; PPDC, Peristaltic Pulse Dynamic Compression

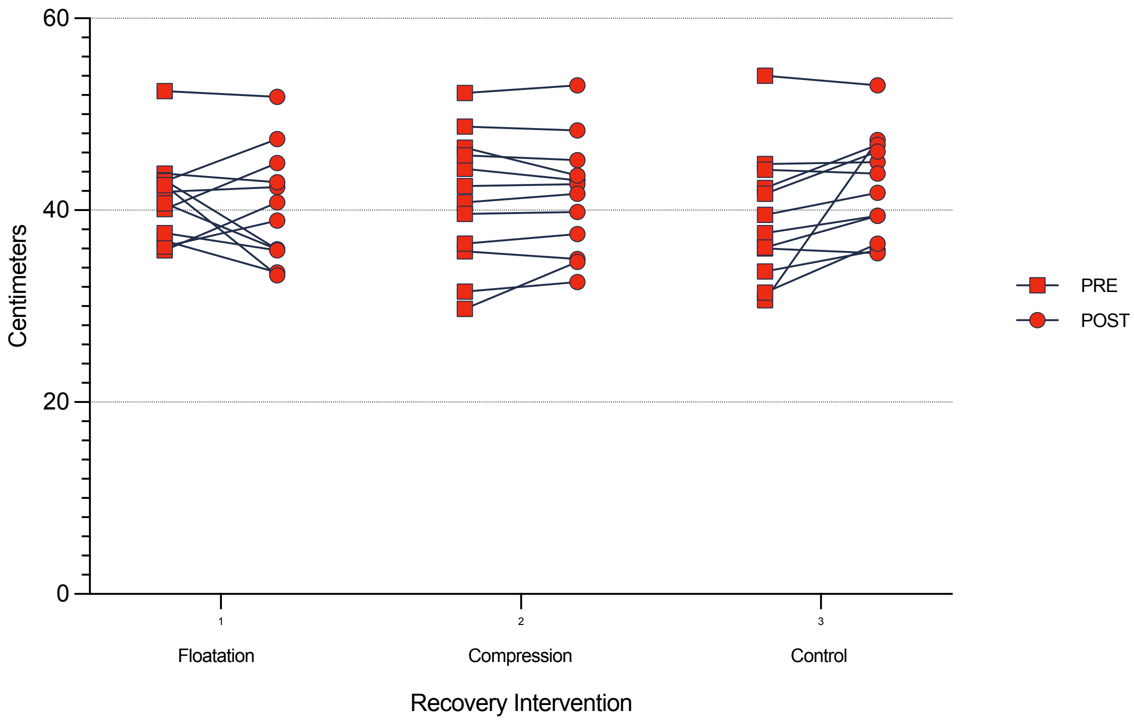

Figure 2.1a. Individual JH by Time Across Intervention.
Note: Floatation = Floatation-REST; Compression = PPDC. Floatation-REST (Pre *M* = 41.17, Post M = 40.29, *p* = .53); PPDC (Pre *M* = 41.14, Post *M* = 41.41, *p* = .63); Control (Pre *M* = 39.32, Post *M* = 42.53, *p* = .04)

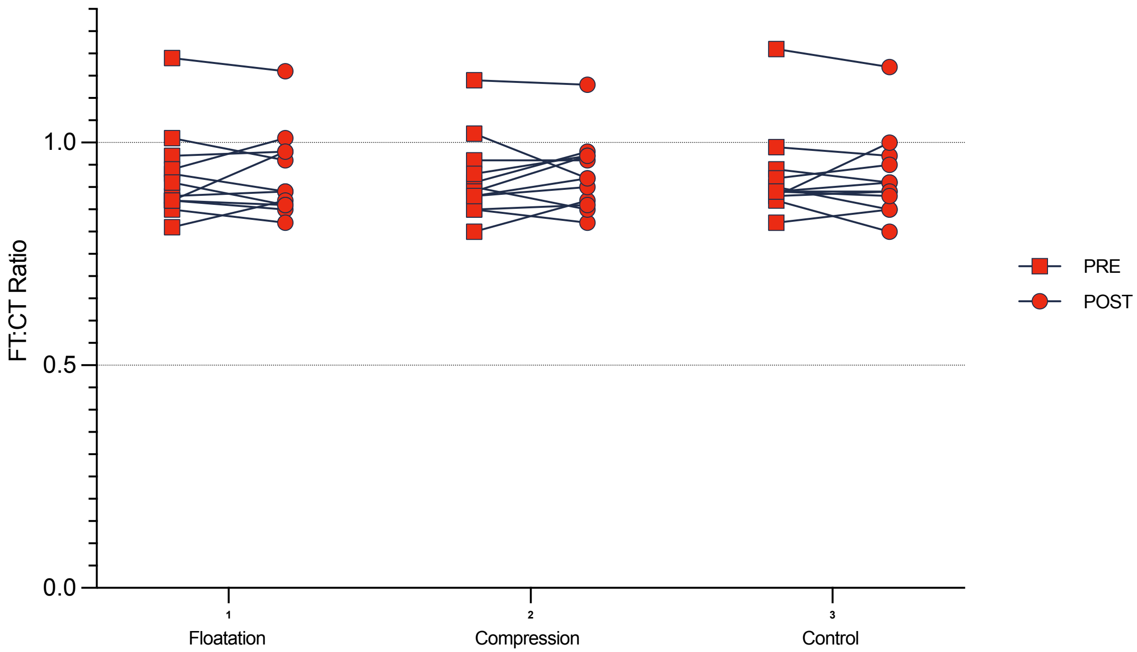

Figure 2.1b. Individual FT:CT by Time Across Intervention
Note: Floatation = Floatation-REST; Compression = PPDC. Floatation-REST (Pre *M* = .93, Post M = .93, *p* = .87); PPDC (Pre *M* = .92, Post *M* = .93, *p* = .47); Control (Pre *M* = .92, Post *M* = .92, *p* = .96).

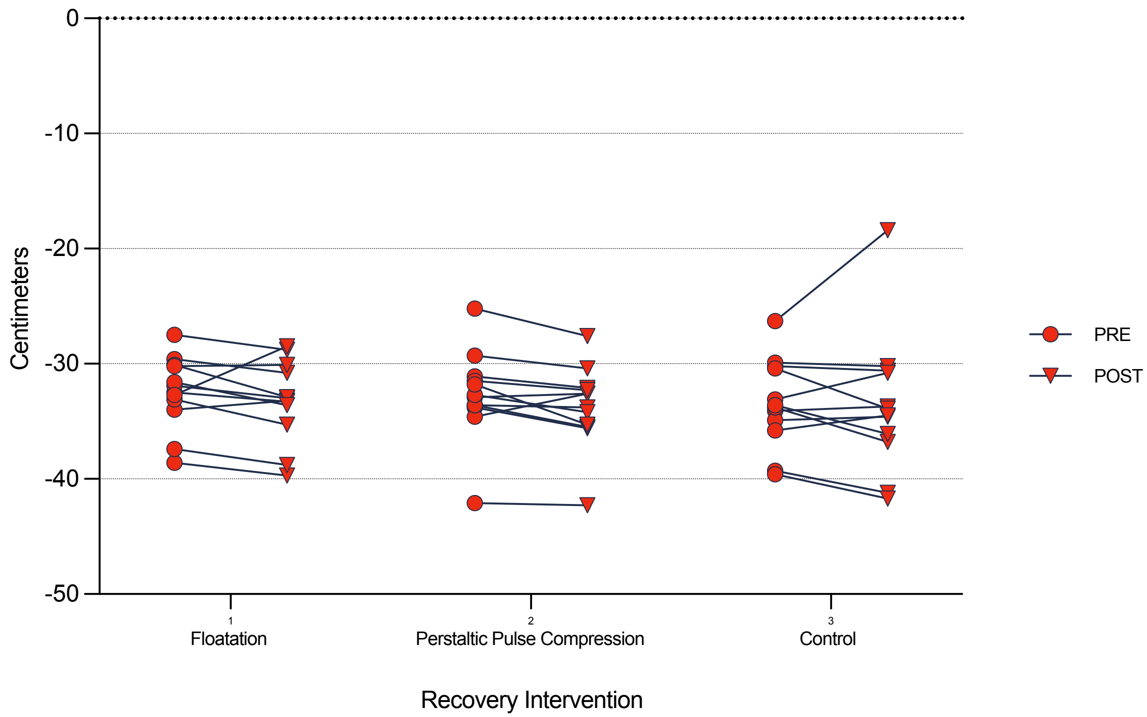

Figure 2.1c. Individual CMD by Time Across Intervention
Note: Floatation = Floatation-REST; Compression = PPDC. Floatation-REST (Pre *M* = -32.43, Post M = -33.42, *p* = .19); PPDC (Pre *M* = -32.68, Post *M* = -33.69, *p* = .03); Control (Pre *M* = -33.42, Post *M* = -33.54, *p* = .89)

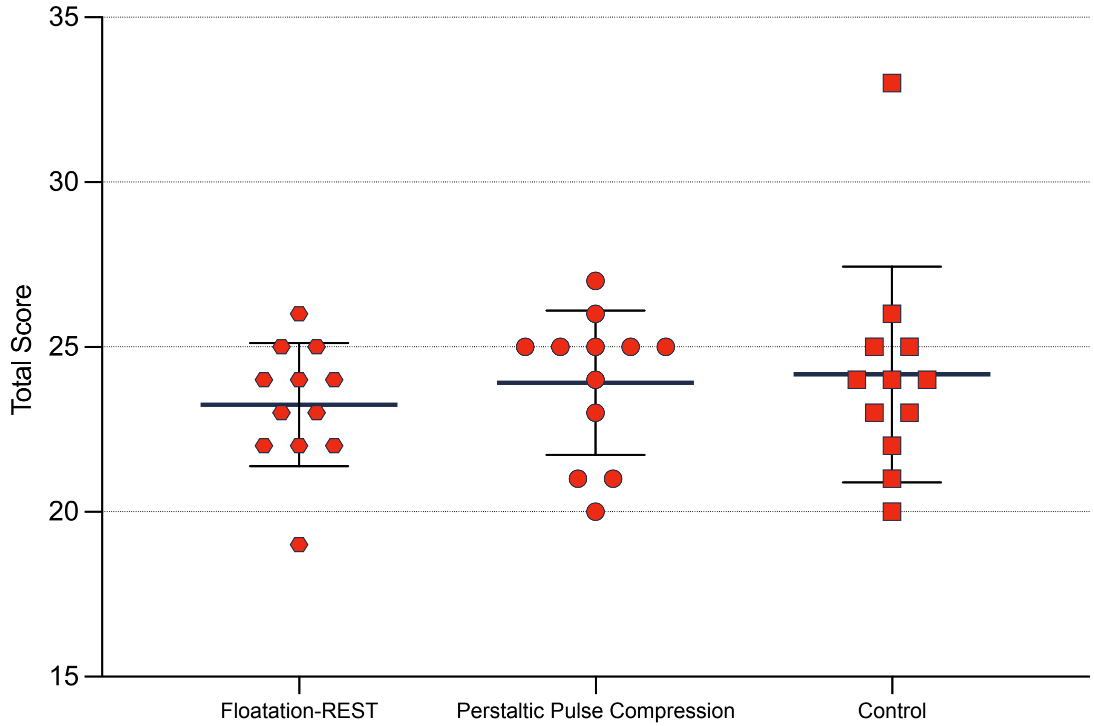

Figure 2.2. Total Wellness Score by Intervention
Note: Floatation = Floatation-REST; Compression = PPDC.

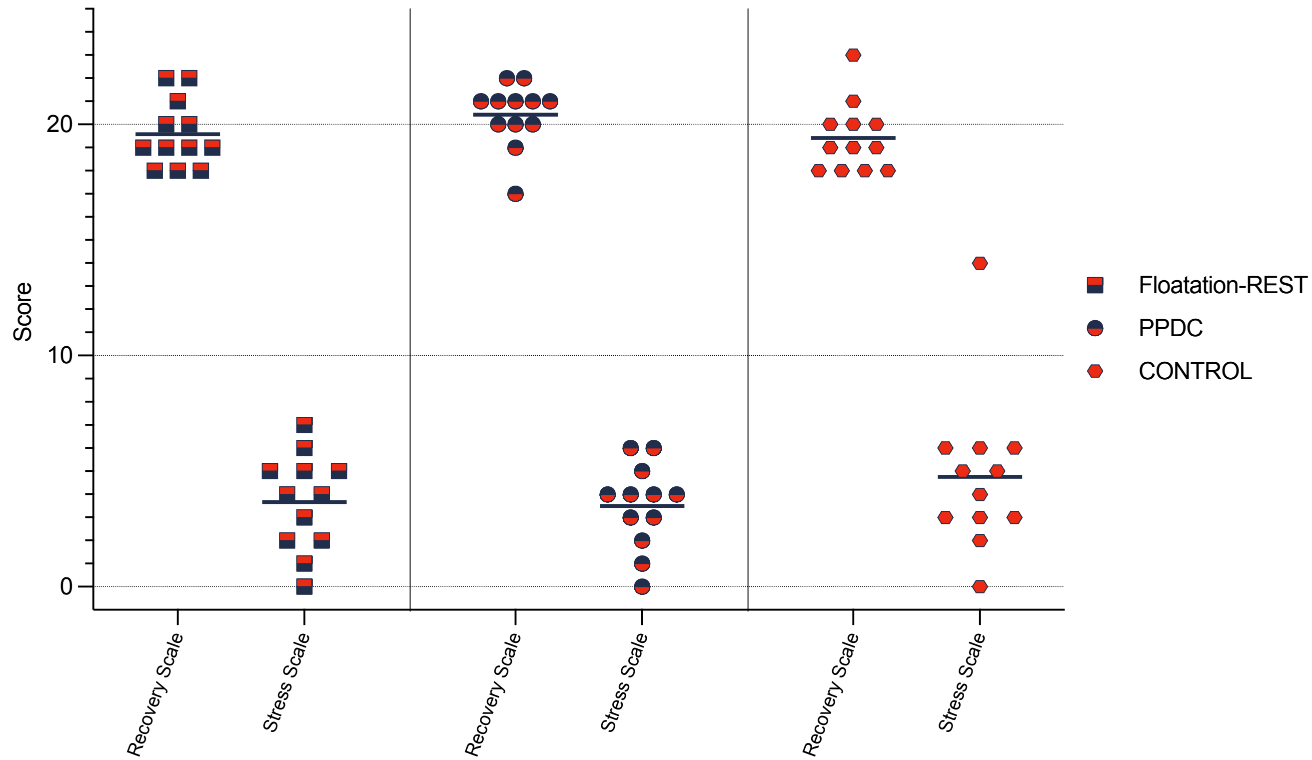

Figure 2.3 Wellness Scores by Scale Across Intervention
Note: Floatation = Floatation-REST; Compression = PPDC.

SECTION II: MANUSCRIPT III

AN EXPLORATORY ANALYSIS OF PYSCHOLOGICAL STRESS AND NEUROMUSCULAR PERFORMANCE DURING THE COMPETITIVE SEASON: A CASE SERIES IN COLLEGIATE BASKETBALL ATHLETES

ABSTRACT

Background: Psychological stressors are known, yet seldom studied factors in athletic performance. Validated psychological instruments are commonly used in clinical settings to assess and track mental health. In sport, there is a need to measure environmental factors and their effects on neuromuscular performance. In collegiate athletics, the demands of academics in addition to the challenges of present-day psychosocial factors may have significant impact on physiological readiness. The purpose of this study was to investigate changes in neuromuscular performance and explore the potential effects of psychological-related factors measured via a validated psychological instrument (CCAPS-34) on countermovement jump performance (CMJ), over a 54-day period of the competitive season and academic calendar in NCAA D1 male collegiate basketball players.

Study Design: Longitudinal, prospective, observational study

Methods: Data from 13 male collegiate basketball athletes (mean ± SD; age, 21.15 ± 1.77yrs; height, 196.55 ± 11.14cm; body mass 94.23 ± 12.62) playing for the same team during the 2022-2023 NCAA basketball season were analyzed over 54-days of the in-season. CMJs and the CCAPS-34 were collected over 6 timepoints during conference and post-season tournament play and the spring semester of the academic calendar for comparison.

Results: Repeated measures ANOVAs revealed statistically significant changes in JH and RSImod over the 6 timepoints during the late in-season, however there were no significant changes for CCAPS-34 measures. There were also no significant Timepoint*PlayStatus effects for CMJ measures. There were also no significant Timepoint*PlayStatus effects for CCAPS-34 measures based on PlayStatus. Moreover, our secondary hierarchical regression analyses revealed that CCAPS-34 measures were not strong predictors of neuromuscular performance in the CMJ in rotational or non-rotational players.

Conclusions: In this cohort of NCAA D1 male basketball student-athletes there were significant reductions in neuromuscular performance during the late in-season. Psychological stress measured via the CCAPS-34, independently, was not a strong predictor of CMJ performance in this cohort of collegiate basketball players.

KEYWORDS: Athlete Monitoring, CCAPS, Mental Health, Basketball, Countermovement Jump,

INTRODUCTION

Psychological stressors are known, yet seldom studied factors in athletic performance. Neuromuscular performance (NMP) underpins the expression of skill in sport and the effects of psychological factors on NMP have not been well investigated despite the acknowledgement by practitioners of the potential negative effects on performance. The health benefits of exercise on mental health have been well investigated across a broad range of age groups with improvements in self-perception, enhanced self-esteem, cognition, and academic achievement.[1–5] Conversely, current societal conditions are increasing psychosocial stress broadly within humanity with significant declines in physical activity and mental health among college aged individuals since the onset of the COVID-19 pandemic.[6] Research has shown an alarming increase in reports of depression, anxiety, and suicidal thoughts with an absence of coping mechanisms in college students. [7] Hence, there is an increasing need to measure psychological stress in college-aged populations.

Participation in sport at the collegiate level comes with additional stress related to team and individual performance in competitions. The current landscape in elite college sports is ever more becoming a business with a reported $15.8 billion of generated revenue in 2019 across all division 1 sports. Much of that revenue is produced by Football and Men's Basketball specifically. This brings added attention to the performance outcomes of teams and individual athletes who participate in these sports. The impact of social media and the accessibility to athletes complicates and compounds the external stressors imposed on today's student-athletes. There is a need in youth and collegiate athletics to prioritize mental health and well-being as 42% of college student-athletes were reported to engage in binge drinking, substance abuse, and other behaviors that can be considered detrimental to physiological readiness and performance in their respective sports.[8,9] Given that clinicians and practitioners are aware of these psychological stressors and the lack of coping mechanisms that result in poor lifestyle behaviors there is a need to better monitor and quantify psychological stressors and the potential negative effects on physiological readiness and performance outcomes.

Collegiate students, including athletes, face numerous psychological challenges, including stress, anxiety, and depression. Understanding the mental health needs of these populations is crucial for providing effective support and intervention. The CCAPS-34 has gained prominence as a comprehensive assessment tool in collegiate health settings due to its multidimensional approach. The CCAPS-34 is a widely recognized self-report questionnaire that measures various psychological symptoms and has been extensively utilized in general collegiate health to assess a range of psychological symptoms and distress.[10,11] Studies have reported its effectiveness in identifying mental health concerns, such as anxiety, depression, and suicidality, among college students. [12] It has demonstrated good internal consistency, test-test reliability, and convergent validity in college students.[12,13] Athletes do experience unique demands related to balancing academic and athletic demands. There is evidence that athletes have reduced levels of distress which may be attributed to their participation in sport yet benefit from treatment with greater symptom reduction in depression, generalized anxiety, and academic distress subscales compared to non-athletes.[14] This underscores the importance of quantifying psychological stress in athlete populations so that proper interventions can be provided when necessary. Furthermore, the CCAPS-34, as a standardized and validate instrument, may help identify specific psychological symptoms and areas of distress specific to athletes that may help institutions facilitate better environments for performance.

Neuromuscular performance can be associated with underpinning physiological factors that contribute to an athlete's capacity to produce muscular mechanical force[15] and subsequently the production of muscular force for the expression of locomotor and sports-specific task execution. Jump testing utilizing force plates have commonly been used to assess and monitor neuromuscular performance and the training and fatigue-related responses in athletes with a varying range of neuromuscular changes noted in conditions of fatigue.[16] The countermovement jump (CMJ) specifically, has emerged as a valid and reliable measure of NMP.[17] The CMJ has also been associated with the bio-motor tasks necessary for sport. Its practicality has also allowed it to emerge as an athlete monitoring tool for evaluation of NMP, specifically in collegiate and professional basketball.[18–20]

The association between psychological stress and NMP in sport has not been well investigated. There is a need to quantify psychological stress in highly visible sports like collegiate basketball and explore the effects of environmentally related psychological stress on NMP while contextualizing the demands of being a NCAA Division 1 student-athlete during the competitive season. Increasing the understanding of the effects of psychological stress on NMP during the season may afford clinicians and practitioners the ability to better create environments conducive to mental health as well as identifying psychologically related neuromuscular fatigue. This may potentially allow for alterations to training in conditions of decreased readiness or more importantly to flag and trigger appropriate interventions (e.g., sports or clinical psychologist) from domain specific stakeholders.

Therefore, the purpose of this exploratory study was to quantify changes in, and relationships between NMP and psychological stress (PS) over 6 weeks during the competitive season of male collegiate basketball players. Specifically, we explored the differences in select CMJ variables, Jump Height (JH) and Reactive Strength Modified (RSImod), and the CCAPS-34 subscales (Academic Stress, Alcohol Use, Depression, Eating Concerns, Frustration-Anger, General Anxiety, and Social Anxiety) weekly during the late in-season. Additionally, we hypothesized that JH and RSImod would have statistically significant changes and those changes would be associated with measures of CCAPS-34 subscales, specifically Academic Stress, General Anxiety, and Social Anxiety.

METHODS

Study Design

An observational repeated measures study design was used to explore changes in NMP and PS in male collegiate basketball players over a 54-day period during the late in-season. Two CMJ kinetic dependent variables were selected as measures of NMP (JH, RSImod) while the independent variables were the subscales of the CCAPS-34 (Academic Stress, Alcohol Use, Depression, Frustration-Anger, General Anxiety, and Social Anxiety). Additionally, we used a hierarchical regression to evaluate the relationships between measures of psychological stress as predictors of CMJ performance at the 6 timepoint across the late in-season. We also sought to investigate differences between play status by comparing rotational versus non-rotational players. For the purposes of this study rotational players are defined as players who averaged minutes greater than 25% of game 40-minute game (>10 minutes). To provide perspective on our results we also recorded contextual data to account for environmental effects.

Participants

Data were collected were from 13 male collegiate basketball players (mean ± SD; age 20.92 ± 1.89yrs; height 196.56 ± 11.15cm; body mass 94.23 ± 12.62kg) from a single National Collegiate Athletic Association (NCAA) Division I Team during the late in-season. For the purposes of this study the late in-season is defined as the period of time ranging from the start of conference play (late December) to the end of post-season tournament play (Mid to Early April dependent on advancement). This season phase is characterized by 2-3 games per week in addition to 2-4 practices per week dependent on the competition schedule. During the in-season, the NCAA permits 20 hours per week of practice, game, and supplemental training (e.g., strength training) and requires 1 day off every week unless the competition schedule does not permit. The team roster included 14 members, however, only 13 members were included due to logistical constraints and limited access to athlete monitoring technology. Participants completed a total of 6 CMJ and CCAPS-34 assessments over the course of 54 days in the late in-season. The study protocol was approved by the university's institutional review board (IRB Protocol #4812). Participants were required to provide informed consent per the University of Virginia IRB despite these measures being collected within the context of the team's routine athlete monitoring procedures. The CCAPS-34 contains items sensitive items pertaining to suicidal ideation and thoughts of harming yourself our others that required an action plan involving sports medicine and sports psychology if a sensitive item was endorsed during the study.

Instrumentation

CCAPS-34 data was recorded using an iPad and Smartabase Kiosk application. The CCAPS-34 items and 5-point Likert scale were previously loaded in the application. The CCAPS-34 is a validated and reliable psychological instrument primarily utilized in college mental health counseling.[21] It is a 34-item instrument with seven distinct subscales that are related to psychological symptoms and distress in college students and incorporates the Distress Index. The CCAPS-34 takes approximately 2-3 minutes to complete, can be used as a brief assessment instrument at any point in treatment and, due to its brevity can be used for repeated measurements.

Neuromuscular Performance

CMJ variables were selected based on previous literature.[17,22,23] Specifically, variables were selected to detect changes in output and jump strategy, kinetics that may be associated with neuromuscular fatigue.[17,24] CMJ variables were also selected based on their relevance to the muscular demands associated with participation in sport.[20,25–28]

CMJ data were collected using the commercially available ForceDecks FD4000 Dual Force Platforms (ForceDecks, Vald Performance, Brisbane, Australia), with a sampling rate of 500Hz. Previous literature suggests that sampling rates greater than 200hz are valid and reliable for the measurement of countermovement jump.[29] ForceDecks software (VALD, Brisbane, Australia) was used to analyze all CMJs variables. CMJ variables of interest are listed, defined, and abbreviated in Table 1.

Data Collection

CCAPS-34

The CCAPS-34 was used to measure PS upon arrival to the training and competition facility. Data collection took place in the locker room on an iPad prior to entering the strength and conditioning center for CMJs and a strength training exposure in the morning hours. Participants were instructed to complete the CCAPS-34 via Smartabase kiosk (iPad) upon arrival to the locker room. Further, participants were asked to complete the test without the aid or influence of other team members. The data collection took place on practice days and were as follows.

Data collection 1: Day 14 following an “off day”

Data Collection 2: Day 21 following an “off day”

Data Collection 3: Day 32 following an “off day”

Data Collection 4: Day 42 following an “off day”

Data Collection 5: Day 48 following a “practice day”

Data Collection 6: Day 54 following an “off day”

There was not a consistent schedule of data collection (e.g., days between measurements) during this study as competition, travel, and training schedule did not permit routine sequencing and administration of the measurements. Data were collected following off days or practice days based on increased availability to the participants to conduct multiple measures (i.e., CCAPS-34 and CMJs). Additionally, the investigators decided psychological measures collected on competition days would be questionable ethically and increase risk of an adverse event. Participants were informed that the data from the CCAP-34 would not be shared with sport coaches, and it would not impact play status or standing within the team. However, if concerning responses were identified in any participants’ CCAPS-34 assessments, an a priori system was established to immediately notify sports medicine and clinical psychology clinicians for formal evaluation.

Countermovement Jump

CMJ assessments were performed in the strength & conditioning center after completing the CCAPS-34 survey and prior to the strength training exposures in the morning. This data collection was part of normal routine athlete monitoring over the course of 54 days. Participants performed a standardized warm up prior to each testing session, which included dynamic stretching and locomotion patterns (e.g., skipping, jogging, and running) which progressed in intensity over the course of the warm-up to prepare participants for maximal jump performance during the CMJ assessments.[18,19] To perform the CMJ, athletes started in the tall standing position, with feet placed hip width to shoulder width apart and hands akimbo. The subject was then instructed to start with equal weight distribution on both force cells. A visual representation of vertical force and weight distribution was displayed on a monitor in front of the participant to provide synchronized and integrated feedback, allowing for the participant to adjust their positioning for equal quantities of body mass to be distributed on each force plate for the start of the jump. Once quiet stance was established the participant was then instructed to lower their center of mass to a self-selected countermovement depth, and then jump vertically "as high and fast as possible". Participants were also instructed to visualize "jumping through the ceiling" to encourage maximal vertical displacement. Finally, participants were instructed to complete the movement by landing in an athletic stance on the force platform. A "quiet stance" was acquired between jumps and the procedure was completed for a total of 3 jumps. If at any point the subject removed their hands from their hips or exhibited excessive knee flexion once airborne, the jump was ruled invalid and repeated. The ForceDecks software uses a 20N offset from the measured body mass, quantified before the jump, to define the start of movement. The average of the three jumps was moved forward for analysis.

Contextual Variables

We recorded data on exposure type (practice, game), competition outcome (win or loss), travel status (yes or no) and high academic demands (yes or no). These contextual variables were selected based on previous literature related to the effects travel fatigue, impacts of game outcomes on well-being, and performance decrements during high academic demands.[30–32] They were hand recorded upon retrospective review of the season and included here for contextual reference. See figure 1.

Missing Data

Given this data was collected in-situ, missing data is not uncommon for logistical reasons such as equipment error and other circumstances. There was one participant who suffered a time-loss injury and did not complete the CCAPS-34 and CMJ at one timepoint. That data was imputed for analysis. This constitutes 1.1% or < 5% of the combined data set for all observations.

Statistical Analysis

All data are reported as means ± SD unless stated otherwise. Statistical analyses were performed using SPSS statistical software (IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp) with an a priori significance level set at $p \leq .05$.

Three separate repeated measures ANOVAs with Bonferroni corrections were used to analyze statistically significant differences in CMJ variables (JH and RSImod) and CCAPS-34 subscales (Academic Stress, Depression, Alcohol Use, Eating Concerns, General Anxiety, and Social Anxiety) across timepoints. The p-value was set a priori at $p < 0.05$ for all analyses. Partial eta squared was used to evaluate magnitude of difference for simple and main effects. Additionally, for pairwise comparisons Cohen's d were calculated to interpret magnitude of difference between pairwise comparisons. Effect sizes were categorized using the following descriptors: ≤ 0.19 – trivial, 0.2-0.49 – small, > 0.5-0.79 – moderate, ≥ 0.8 – large.[33]

To investigate difference in Play Status, mixed model ANOVAs with Bonferroni corrections were performed to analyze statistically significant differences between subjects in CMJ variables (JH and RSImod) and CCAPS-34 subscales (Academic Stress, Depression, Alcohol Use, Eating Concerns, General Anxiety, and Social Anxiety) across timepoints.

Hierarchical multiple regressions were performed on each time point to determine if the addition of play status improved the prediction of JH and RSImod over and above CCAPS-34 subscales (Academic Stress, Depression, Alcohol Use, Frustration/Anger, Eating Concerns, General Anxiety, and Social Anxiety) alone.

RESULTS

Jump Height

A one-way repeated measures ANOVA revealed that mean JH scores were significantly different across timepoints $F(5,60) = 6.072$, $p < .001$, partial $\eta^2 = .336$). Post hoc testing revealed a statistically significant large 5.64 cm decrease in jump height (p = .015, 95% CI [0.87, 10.41], Cohen's d = 1.20, 95% CI [2.03, 0.36]) from timepoint 4 (M = 40.15, SD = 4.04) to timepoint 5(M = 34.51, SD = 5.29). Additionally, there was a statistically significant large 5.23 cm decrease (p = .004, 95% CI [1.46, 9.00], Cohen's d = 1.22, 95% CI [2.06, 0.39]) from timepoint 4 to timepoint 6 (M = 34.91, SD = 4.50). Descriptive statistics and results are presented in Table 2 and Figure 2.

RSImod

A one-way repeated measures ANOVA also revealed that mean RSImod scores were significantly different across timepoints. $F(5,60) = 8.392$, $p < .001$, partial $\eta^2 = .412$). Post hoc testing revealed a statistically significant large 9.38 unit decrease in RSImod ($p = .01$, 95% CI [1.843, 17.23], Cohen's $d = 1.19$, 95% CI [2.02, .36]) from timepoint 4 ($M = 74.77$, $SD = 7.55$) to timepoint 5 ($M = 65.24$, $SD = 8.45$) and a significant large 8.94 unit decrease ($p = .03$, 95% CI [.52, 17.37], Cohen's $d = 1.19$ 95% CI [2.02,.35]) from timepoint 4 to timepoint 6 ($M = 65.83$, $SD = 7.52$). Descriptive statistics and results are presented in Table 2 and Figure 3.

Play Status

We observed no statistically significant interaction between play status and timepoints on JH $F(5,55) = 2.31$, $p = .057$, partial $\eta^2 = .17$) or RSImod $F(5,55) = 1.28$, $p = .287$, partial $\eta^2 = .10$.

CCAPS-34

A repeated measures ANOVA revealed no statistically significant changes for CCAPS-34 subscale measures Academic Stress ($F(5,60) = 2.11$, $p = .077$, partial $\eta^2 = .15$), Alcohol Use ($F(5,60) = 1.0$, $p = .426$, partial $\eta^2 = .08$), Depression ($F(5,60) = 0.45$, $p = .81$, partial $\eta^2 = .04$), Eating Concerns ($F(5,60) = 1.13$, $p = .352$, partial $\eta^2 = .09$, Frustration/Anger ($F(5,60) = 0.78$, $p = .568$, partial $\eta^2 = .06$), General Anxiety $F(5,60) = 1.06$, $p = .390$, partial $\eta^2 = .08$), or Social Anxiety $F(5,60) = 1.09$, $p = .377$, partial $\eta^2 = .098$) across timepoints. See figure 4.

Play Status

We also observed no statistically significant Timepoint*PlayStatus interaction on CCAPS-34 measures F(7,35) = 1.05, p = .400, partial η^2 = .122)

Hierarchical Regressions Analysis

Jump Height

At timepoints 5 and 6 a hierarchical multiple regression was run to determine if the addition of the seven subscales of the CCAPS-34 (Academic Stress, Alcohol Use, Depression, Eating Concerns, Frustration/Anger, General Anxiety, and Social Anxiety improved the prediction of JH over and above Play Status alone. See table 3 for full details on each regression model.

At timepoint 5, there was linearity as assessed by partial regression plots and plots of studentized residuals against predicted values. There was independence of residuals by a Durbin-Watson statistic of 2.36. There was homoscedasticity, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater ±3 standard deviations, no leverage greater 0.2, and values for Cook's distance above 1. The assumption of normality was met, as assessed by Q-Q Plot.

The full model of play status, Academic Stress, Alcohol Use, Depression, Eating Concerns, Frustration/Anger, General Anxiety, and Social Anxiety to predict JH (Model 2) was not statistically significantly, R^2 = .269, F(7,5) = 0.263, p = .945, adjusted R^2 = -.754. The addition of CCAPS-34 Subscales to the prediction of JH (Model 2) did not lead to statistically significant increase in R^2 of .168, F(6,5) = 0.192, p = .966.

At timepoint 6, there was linearity as assessed by partial regression plots and plots of studentized residuals against predicted values. There was independence of residuals by a Durbin-Watson statistic of 2.430. There was homoscedasticity, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater ±3 standard deviations, no leverage greater 0.2, and values for Cook's distance above 1. The assumption of normality was met, as assessed by Q-Q Plot.

The full model of play status, Academic Stress, Alcohol Use, Depression, Eating Concerns, Frustration Anger, General Anxiety, and Social Anxiety to predict JH (Model 2) was not statistically significantly, $R^2 = .177$, $F(7,5) = .154$, $p = .986$, adjusted $R^2 = -.975$. The addition of CCAPS-34 Subscales to the prediction of JH (Model 2) did not lead to statistically significant increase in R^2 of .117, $F(6,5) = 0.119$, $p = .989$.

DISCUSSION

To our knowledge this is the first study to explore the effects of psychological factors on neuromuscular performance in collegiate basketball. In this study, we report data from force plates utilizing selected output and strategy-related CMJ variables[17,24] data recorded from an ecologically validated psychological measures from the CCAPS-34[21] while contextualizing a portion of late in-season phase of an NCAA D1 season. Our results were not consistent with our hypothesis and call into question the effects of psychologically related stress on neuromuscular performance, as assessed by CMJ, in male collegiate basketball athletes. The main findings of this study indicate that there were significant changes in JH and RSImod across timepoints during the late in-season and CCAPS-34 subscale measures are limited in explaining variance for JH and RSImod.

NMP

Jump Height and RSImod

The results of this study showed that mean JH scores were significantly different across the late in-season (timepoint 1 (M = 38.19, SD = 6.74), timepoint 2 (M = 38.23, SD = 5.12), timepoint 3 (M = 38.07, SD = 5.25), timepoint 4 (M = 40.15, SD = 4.04), timepoint 5 (M = 34.51, SD = 5.29) and timepoint 6 (M = 34.91, SD = 4.50) as shown in figure 2a. We observed significant a 14% reduction in JH at timepoint 5 compared to timepoint 4 and a 13% reduction from timepoint 4 to 6,after a 5.2% increase from timepoint 3 to 5, suggesting the presence of neuromuscular fatigue and decreased capacity to displace center of mass in the CMJ. Practically, reductions in vertical force producing capacity and decreased kinetic outputs could have negative effects on sport performance broadly and undesirable implications on expression of skill in basketball specifically. More importantly, these findings are seen during a critical period of the late in-season which may have significant effects on game outcomes. Despite these reductions we did not see a statistically significant association with NMP and measures from CCAPS-34 through our hierarchical regression analysis. This suggests that our quantification of psychological stress independently did not have significant effects on NMP in this study on collegiate basketball players.

We also found that RSImod scores were significantly different across the late in-season (timepoint 1 (M = 72.52, SD = 9.06), timepoint 2(M = 71.49, SD = 10.19), timepoint 3 (M = 72.50, SD = 10.21), timepoint 4 (M = 74.77, SD = 7.55); timepoint 5 (M = 65.24, SD = 8.45), and timepoint 6 (M = 65.83, SD = 7.52). Refer to figure 2b. Similar to observations in the JH, we observed a significant 12.7 unit reductions in RSImod at timepoint 5 compared to timepoint 4 and a 11.9% unit decrease from timepoint 4 to 6, after an 3% increase from timepoint 3 to 4, suggesting the presence of neuromuscular fatigue, decreases in force and power characteristics (e.g., peak force, rate of force development, time to peak force) as well as potential alterations in time to takeoff. As stated previously, the practical implications for reductions in RSImod could have negative effects on performance outcome with increases in time to takeoff (TTT) equating to longer durations to potentially execute sport related tasks when milliseconds matter in competitive scenarios.

In a collegiate basketball competition, there are 200 minutes that can be divided amongst the 5 players who are on the court during a 40-minute (e.g., Two 20 minutes halves) game play. Coaches must make play status decisions based on tactical objectives for the season and individual games played throughout. This typically evolves into a PlayStatus casting system of rotational and non-rotational players. "Rotational players" inherently face different psychological (e.g., game-related stress, pressures associated with social media attention, etc.) and physiological (sports-related training loads, strength training related loads, etc.) stressors compared to "non-rotational players". In our study we found significant differences between these two groups for JH. We observed significantly lower JH measures in the "non-rotational' group. This finding may suggest several effects that warrant further investigation. First, it is possible that the physical preparation objectives of these players (e.g., increase strength and power capacities) with increased strength training exposures in addition to sport-related training load, may have resulted in prolonged periods of decreased neuromuscular readiness that can be associated with the effects of supercompensation and fitness-fatigue modeling.[16,34,35] Secondly, and more important specific to sport, the ability to exhibit higher levels of neuromuscular performance may be an important factor in what differentiates play status in collegiate basketball. This would be consistent with previous findings in basketball players that there are strong relationships between physical characteristics, positions, level of play, and roles in male elite basketball.[36–39]

Psychological Stress

The results of this exploratory study revealed no significant changes in CCAPS-34 measures during the late in-season and no significant association with psychological measures as predictors for CMJs variables overall or when controlling for PlayStatus.

Contextual Factors

Figures 1 and 4. illustrates practices, games, outcomes, travel, site status, and high academic stress with CCAPS-34 subscales. Contextual data would suggest that the CCAPS-34 did exhibit an ability to detect periods of high academic stress as the CCAPS-34 subscale, Academic Stress exhibited a timepoint effect, $F(5,60) = 2.107$, $p = .077$, partial $\eta^2 = .149$) moving towards significance. There was a .461 unit increase in mean Academic Stress from week 3 to week 4, and subsequent identical .461 unit decreased from week 4 to week 5 that coincided with increased academic demand (e.g., midterms) in the contextual data. This observation strengthens the argument that use of the CCAPS-34 practically may provide insights into periods of increased academic demand.

Limitations & Strengths

There are strengths to this study. This was an applied study conducted in a team setting which contributes to ecological validity and has practical and clinical implications as its study design may be implemented in real world settings to monitor student-athlete health and well-being. There are also limitations to this study. The length of time data was collected was limited to 54 days which decreased generalizability across the entire season of training year. We also did not account for other factors that may have explained NMP (e.g., external training load, session RPE, etc.). Natural experiments in elite sport settings, such as occurred in this study, are often limited to small sample sizes which make inferential statistics difficult for interpretation and generalizability.

Considerations for Future Research

Future studies should investigate differences amongst several teams to increase the sample size. Investigations should seek to add more explanatory variables into the models to increase the multifactorial nature of stressor in team sports at the collegiate level. Investigation of differences among position groups, class, and across season phases is also warranted. Investigations into sex differences is also recommended to understand differences between male and female student-athletes relative to societal expectations and coping mechanism. External training load derived from accelerometry, or other wearable devices should also be considered to explain the fluctuations in neuromuscular performance.

CONCLUSIONS

The results of this exploratory study showed decreases in JH and RSImod across the late in-season phase in this cohort. Changes in psychological stress did not independently have significant effects on NMP. However, the dynamic environment and multifactorial stressors associated with the demands of being a collegiate athlete are difficult to quantify in totality, yet the CCAPS-34 did appear to capture a period of high academic stress. Future research should seek to better quantify and understand contextualized factors associated with the demands of being a male collegiate basketball athlete.

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Table 3.1. Countermovement (CMJ) Variables and Definitions

Variable	Abbreviation	Description
Jump Height [impulse-momentum]	JH	Jump Height calculated by taking velocity at the instant of take-off and predicting the maximum vertical displacement of the Centre of Mass based on body mass (measured in centimeters). May be considered an output variable.
Reactive Strength Index-Modified	RSImod	Flight Time divided by contraction time. May be considered a strategy-related variable.

Table 3.2. Descriptive Statistics for CMJ and RSImod Across Timepoint

	JH		RSImod	
Timepoint	*M*	*SD*	*M*	*SD*
1	38.19	6.74	72.52	9.06
2	38.23	5.12	71.49	10.19
3	38.07	5.25	72.50	10.20
4	40.15	4.04	74.77	7.55
5	34.51	5.29	65.24	8.45
6	34.91	4.50	65.83	7.52

Data presented as Mean (Standard Deviation). JH = Jump Height; RSImod = Reactive Strength Index-Modified.

Table 3.3. Hierarchical Regression Predicting JH and RSImod from PlayStatus and CCAPS-34

	JH	JH	JH		RSImod	RSImod	RSImod	
	PlayStatus	PlayStatus+CCAPS-34	Sig. F Change		PlayStatus	PlayStatus+CCAPS-34	Sig. F Change	
Timepoint	R^2	R^2		ΔR^2	R^2	R^2		ΔR^2
1	.151	.385	.903	.234	.279	.422	.960	.143
2	.006	.187	.968	.180	.254	.353	.987	.099
3	.235	.680	.445	.445	.332	.799	.242	.467
4	.055	.323	.957	.268	.416	.733	.693	.317
5	.000	.312	.378	.312	.101	.269	.966	.168
6	.016	.438	.709	.422	.060	.177	.989	.117

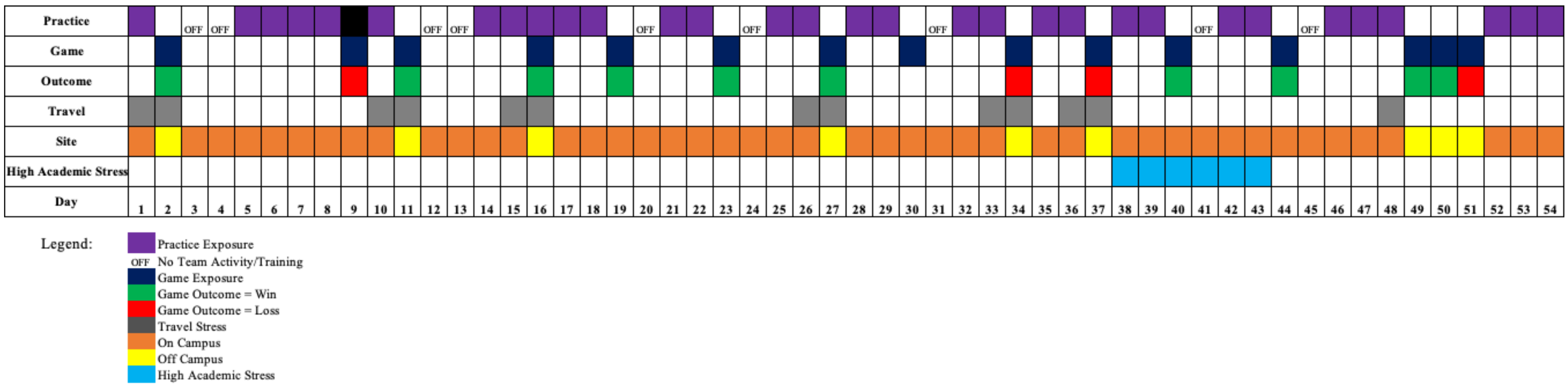

Figure 3.1. Contextual Data for Practice, Game, Win-Loss Outcome, Travel, and High Academic Stress

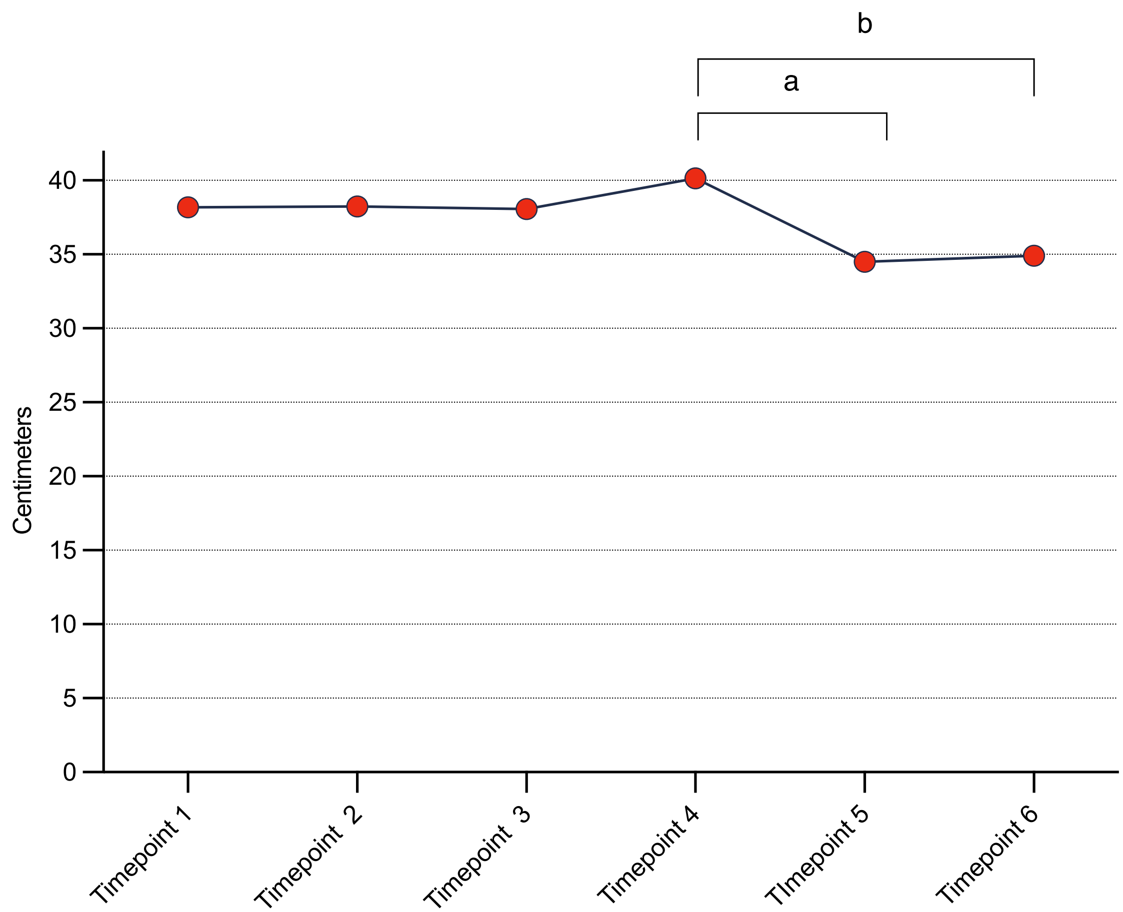

Figure 3.2. JH Across Timepoint
Data presented as Mean; a = Significant difference between Timepoint 4 and Timepoint 5; b = Significant difference between Timepoint 4 and Timepoint 5; Statistical significance set at $p < 0.05$.

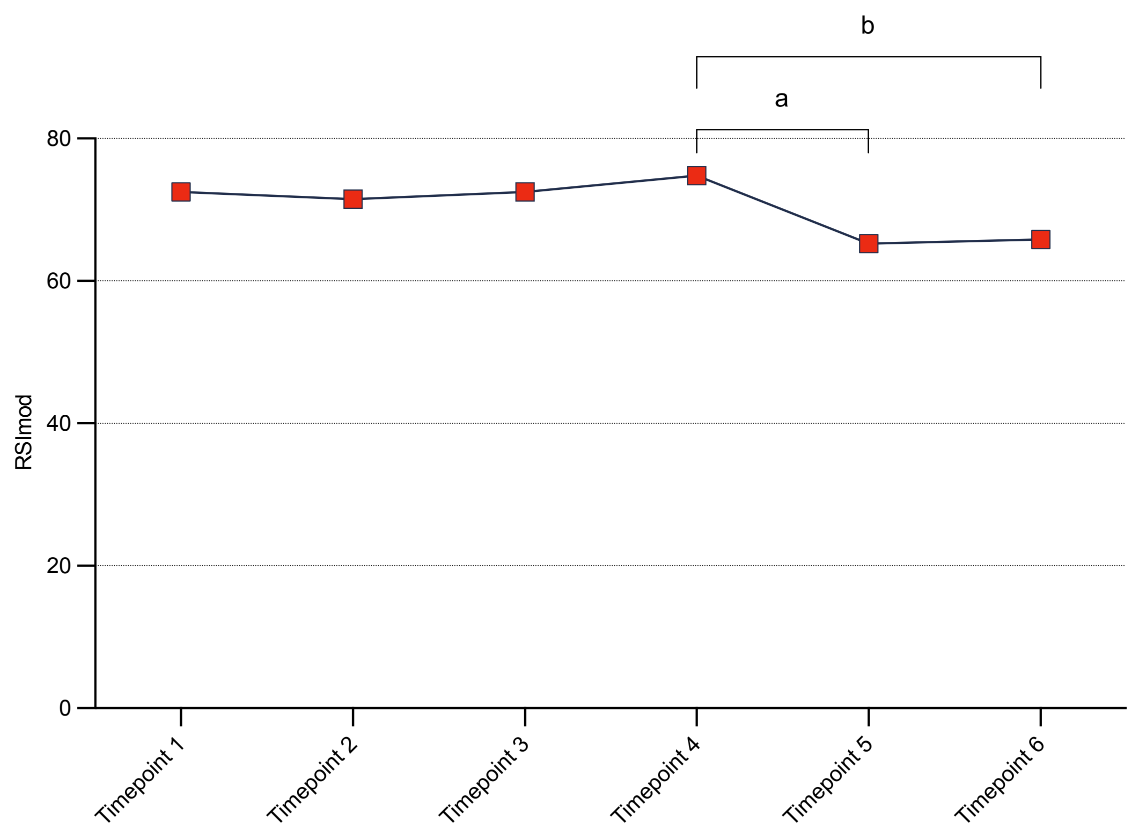

Figure 3.3. RSImod Across Timepoint
Data presented as Mean; a = Significant difference between Timepoint 4 and Timepoint 5; b = Significant difference between Timepoint 4 and Timepoint 5; Statistical significance set at $p < 0.05$.

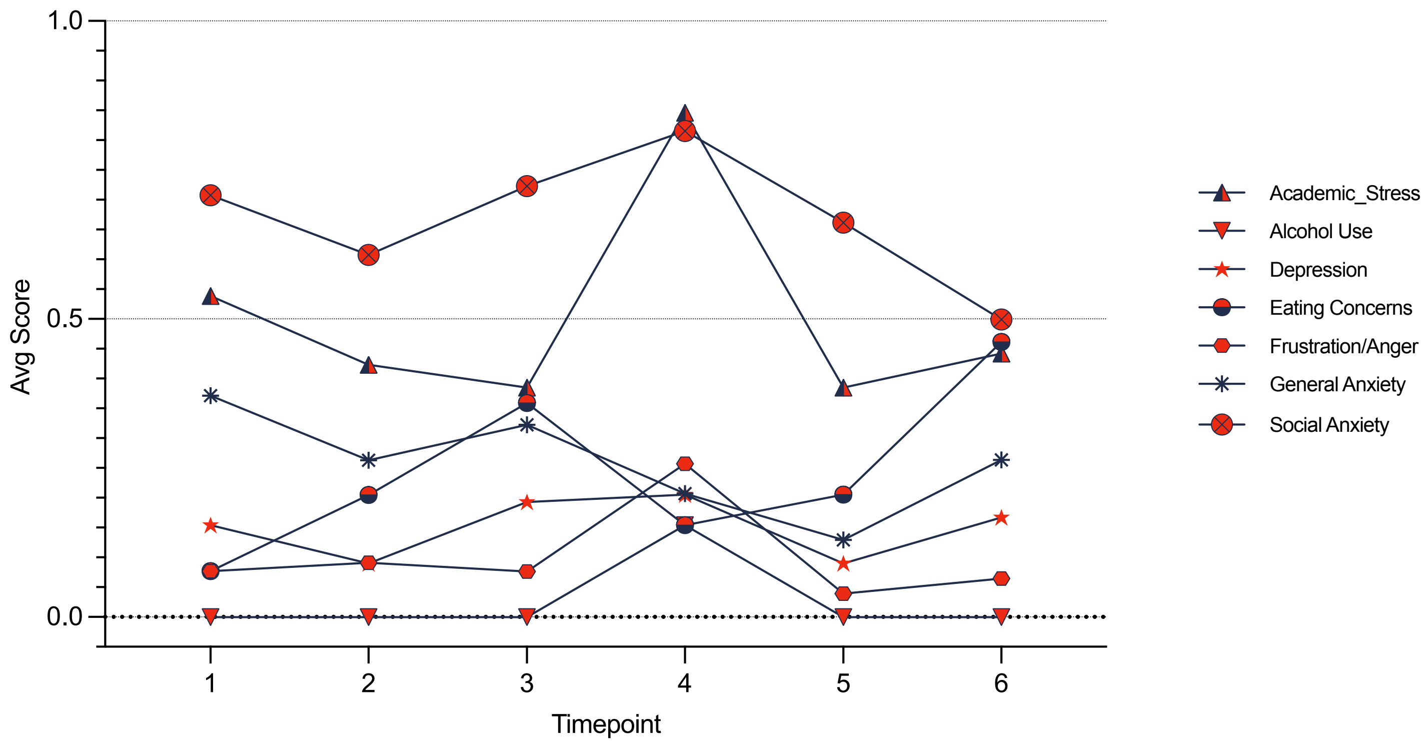

Figure 3.4. CCAPS-34 Subscales Across Timepoint
Data presented as Mean.

APPENDIX A

THE PROBLEM

Neuromuscular performance can be regarded as the ability of neuromuscular systems to functionally control and drive movements by appropriate integration, coordination and use of sensory feedback, reflex activity, central motor drive, muscle recruitment pattern, muscular excitation-contraction coupling, and substrate availability. [1,2] Neuromuscular performance effectively, is the ability of the human movement system to maintain postural and motor control against gravity in static and dynamic environments where the generation of force is necessary to complete a motor task through coordinated limb movement via muscular contraction. This definition of NMP is widely accepted in the literature to be relevant to general fitness, activities of daily living (ADL) and sporting performance specifically. [1]

NMP can be assessed through a variety of methods. In the team sport setting, practicality and efficiency are critically important in navigating the environmental complexities related to chaotic and compressed schedules, athlete engagement, and the challenges of maintaining validity and reliability in data collection when time is a primary constraint. The use of the countermovement jump (CMJ) and force platforms has emerged as a practical test and tool to measure and assess NMP as well as monitor neuromuscular fatigue (NMF) and recovery in response to training. [3,4] Currently, kinetic measures derived from the CMJ utilizing force platforms are being used to elucidate greater understanding of vertical force production in jumping tasks and associations with neuromuscular readiness (NMR). Readiness in regard to the neuromuscular system can be considered as the state of being prepared for a movement-oriented task demand. Dependent on a multitude of factors related to the stages of fitness-fatigue modeling [5,6] or general adaptation syndrome [7] an athlete may perform based on the level of optimization consistent with where they fall within the adaptation process.

The CMJ provides a time efficient, non-fatiguing assessment that fits well in team sport. Early research of the CMJ and its use of the stretch shortening cycle (SSC) [2,8] focused primarily on gross output measures (e.g., jump height) and concentric kinetics (e.g. force and power). The evolution of the CMJ and the work of Gathercole et al, 2015 among others has shown that a more in-depth evaluation of alternative kinetic variables are warranted for understanding the multifaceted and complex phenomenon of fatigue and dose-response after training. [3] These alternative CMJ variables investigating both eccentric and concentric components (i.e., eccentric duration, concentric duration, force and 0 velocity, etc.) may suggest changes in jump strategy in conditions of fatigue. Remarkably, athletes exhibited an ability to maintain output measures in traditional kinetic measures exhibited in non-fatigued states while fatigued [9]. These findings have allowed for contemporary practitioners to engage in analyses of the CMJ with greater potential to explain trends and fluctuations in observed NMP.

Optimizing athlete readiness is a complex task requiring coaches, clinicians, and practitioners to manage the physical, physiological, and psychological state of athletes weekly, daily, and at times hourly in an effort to positively influence injury risk and competitive outcomes. This task requires pertinent and reliable information be accessible to inform decision making specific to athlete welfare and the training constructs imposed by coaches. Proxy measures to quantify readiness are plentiful in today's environment in which technology and wearables are utilized by teams and athletes at virtually every level of sport.

As previously stated, the use of force plates to measure, analyze, and provide insights into performance related factors specific to the neuromuscular system and lower extremity force production have emerged as a valid and reliable tool for inferring levels of neuromuscular readiness, fatigue, adaptation, and recovery. [3,10,11] In collegiate basketball specifically, the use of CMJ measures to glean greater understanding into dose response to external training load (eTL) has been investigated. Increases in eTL have been found to illicit changes in the ratio of flight time to contraction time (FT:CT) and RSImod with increased PlayerLoad /min, which is indicative of strategy changes to complete the CMJ. [12]

The reality in the applied setting and in in-situ research is that the use of the CMJ to measure neuromuscular performance (NMP) has not yet provided extensive research and insights into the responses and associations between factors outside of eTL. Practically, there are many variables known to pose potential confound, system bias, and noise into our understanding of neuromuscular status and dose-response to training, competition, and other ecological factors. Ecological factors can be considered as the relationship of humans to their physical environment and surroundings. There has been limited research investigating ecologically related variables and their concurrent connection to eTL and NMP. Wearable technology now affords scientists the ability to accurately measure ecological factors like two-stage sleep classification (e.g., duration). [13] Additionally, the use of passive and active recovery interventions (e.g., hydrotherapy, compression, percussion, etc.) as an ecological factor are prevalent in team settings with modest investigation and little evidence into their effects on NMP. Potentially the most important ecological factor, psychological related stressors imposed on athletes outside of training sessions, practices, and competitions (e.g., academic, anxiety, depression, etc.) have not been well accounted for and investigated in collegiate sport broadly.

In total, there is a scientific need to investigate the effects of ecological related factors on NMP in collegiate sport, and specifically in basketball. The overarching theme of this dissertation is to evaluate the relationships of sleep, recovery intervention, and psychological stress on NMP utilizing data collected from the CMJ, external training load, sleep duration, as well as self-reported wellness and psychological survey instruments.

EXPERIMENTAL HYPOTHESES

Specific Aim I: To investigate the effects of sleep duration on neuromuscular performance, shooting accuracy, and self-reported wellness during the preseason training phase in male collegiate basketball players.

Primary Hypothesis I: Following worst night sleep duration there would be decreases in JH, FT:CT, shot accuracy, and self-reported measures of wellness compared to measures following "best" night sleep durations.

Specific Aim II: Evaluate the effects of recovery modality on NMP and perceived wellness during the early in-season in male collegiate basketball players.

Hypothesis IIa: Athletes receiving Floatation-REST will experience increased recovery and exhibit greater JH, FT:CT, and RSImod measures pre to post in the CMJ compared to other recovery interventions.

Hypothesis IIb: Additionally, we hypothesize that athletes will report increased measures of wellness after receiving Floatation-REST compared to PPDC and control interventions.

Specific Aim III: To quantify changes in, and relationships between NMP and psychological stress during the competitive season of male collegiate basketball players.

Primary Hypothesis IIIa: JH and RSImod would have statistically significant changes and those changes would be associated with measures of CCAPS-34 subscales, specifically Academic Stress, General Anxiety, and Social Anxiety

Secondary Hypothesis IIIb: There would be significant differences in NMP and psychological stress by PlayStatus.

ASSUMPTIONS

Manuscript I

1. Participants wore and utilized the Oura Ring correctly during sleep conditions and data were collected uniformly across the cohort.
2. Participants gave maximal effort during all countermovement jump assessments.
3. Participants gave maximal effort during the shooting task.
4. Participants were honest and accurate while completing the Short Stress Recovery Survey (SRSS).

Manuscript II

1. Participants were honest and accurate while completing the Short Stress Recovery Survey
2. Participants completed the entire prescribed duration for assigned treatment.
3. Participants utilized the prescribed level of compression throughout the peristaltic pulse dynamic compression treatment.

4. Participants did not utilize sound and sight features available in the Flotation-REST treatment.
5. Participants refrained from basketball-related activities in the control treatment.
6. Participants gave maximal effort during all countermovement jump assessments.

Manuscript III

1. Participants gave maximal effort during all countermovement jump assessments.
2. Participants were honest and accurate while completing the CCAPS-34 instrument.

DELIMITATIONS

Manuscript I

1. Participants were recruited from the men's varsity basketball team at the University of Virginia
2. Participants were between the ages of 17-24 years of age.
3. Findings from this study only apply to collegiate men's basketball players.
4. Participants with significant musculoskeletal injury that may affect testing were excluded.
5. Basketball training sessions were performed in the team setting to maximize ecological validity.

Manuscript II

1. Participants were recruited from the men's varsity basketball team at the University of Virginia
2. Participants were between the ages of 17-24 years of age.
3. Findings from this study only apply to collegiate men's basketball players.

4. Participants with significant musculoskeletal injury that may affect testing were excluded.
5. Participants with significant skin irritation (e.g., rash, cuts, etc.) were excluded or reordered for Floatation-REST treatment.
6. Basketball training sessions were performed in the team setting to maximize ecological validity.

Manuscript III

1. Participants were recruited from the men's varsity basketball team at the University of Virginia
2. Participants were between the ages of 17-24 years of age.
3. Findings from this study only apply to collegiate men's basketball players.
4. Participants with significant musculoskeletal injury that may affect testing were excluded.
5. Participants who flagged for sensitive item responses were excluded from data collection and referred appropriate stakeholders.
6. Basketball training sessions were performed in the team setting to maximize ecological validity.

LIMITATIONS

Manuscript I

1. The cohort for this study was a convenience sample of men's varsity basketball players at the University of Virginia.
2. The results are only generalizable to male collegiate basketball players.

3. While participants were asked to maintain normal sleep strategies, sleep outside of previous night was not accounted for (lag effects, sleep banking, sleep extension, daytime napping).
4. Sleep quality was not accounted for in this study.

Manuscript II

1. The cohort for this study was a convenience sample of men's varsity basketball players at the University of Virginia.
2. The results are only generalizable to male collegiate basketball players.
3. Participants were only exposed to a recovery treatment on a singular occurrence.
4. Participant were instructed to maintain their normal dietary strategy and sleep patterns; environmental controls were not strictly enforced.

Manuscript III

1. The cohort for this study was a convenience sample of men's varsity basketball players at the University of Virginia.
2. The results are only generalizable to male collegiate basketball players.
3. While participants were asked to maintain normal sleep strategies, their compliance and sleep duration was not monitored and not controlled.

SIGNIFICANCE OF THE STUDY

Identifying neuromuscular responses to sleep, recovery interventions, and psychological stressors potentially provide coaches, clinicians, and performance practitioners with greater information and understanding into the potential effects of ecologically related factors that often go unaccounted for in practical settings. The ability to investigate sleep duration and its ramifications on skill expression and NMP allow recognition and identification of team and individual behavioral patterns and their effects on performance in critical underpinning factors. In addition, understanding the most effective recovery modality at the team and individual level may allow for more precision in treatment prescription for recovery from training stress. It also may allow for more informed decision making and promote increased economic efficiency for sports teams seeking effective modalities. Furthermore, attempting to quantify psychological stress provides the opportunity to establish insight into the origin fatigue and the confounding factors outside of traditional external training load.

This potentially provides practitioners the ability better understand the impact of known stressors and identify an instrument that may be sensitive enough to flag and activate a course of action to be optimize NMP and competitive outcomes. The culmination of this work will aid in reducing the risk of under-recovery, maladaptation, mental health deterioration, reduce injury risk while potentially promoting increases in athlete readiness, welfare, recovery, and availability. More importantly, this dissertation will hopefully provide a call to action for an increased future research “in-situ” and the discovery of other factors influencing athletes in the real world.

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APPENDIX B

REVIEW OF LITERATURE

The purpose of this dissertation was to examine neuromuscular performance changes measured via force plates and associations to sleep, recovery modality, and psychological stress while accounting for external training load in a cohort of NCAA collegiate basketball athletes. Additionally, this study sought to investigate the effects of sleep on a sport-related skill (i.e., shooting percentage) in a novel basketball shooting task.

SECTION I. NEUROMUSCULAR PERFORMANCE

Neuromuscular performance can be regarded as the ability of the neuromuscular system to functionally control and drive movement through sensory feedback, coordination, reflex activity, central motor drive, muscle recruitment patterning and excitation contraction coupling[1,2] The neuromuscular system is comprised of complex subsystems, the musculoskeletal system (muscle tissue and skeleton) and the nervous system (brain, spinal cord, efferent and afferent neural pathways). Functionally, the communication between the nervous system (i.e., neurons) and the muscles produces human movement through muscular contraction.

The neuromuscular junction is a chemical synapse between motor neuron and muscle fiber. Synaptic transmission at the neuromuscular junction begins when an action potential reaches the presynaptic terminal of a motor neuron, which activates voltage-gated calcium channels to allow for calcium ions to enter the neuron. Calcium binds to sensor proteins on synaptic vesicles triggering the release of a neurotransmitter from the motor neuron into the synaptic cleft. Motor neurons then release the neurotransmitter acetylcholine, which diffuses across the synaptic cleft and binds to the sarcolemma. The binding of acetylcholine to the receptor depolarizes the muscle fiber and results in muscular contraction.[3,4] In sport, this process produces the movements we utilize to complete bio-motor task demands like running and jumping.

SECTION II: COUNTERMOVEMENT JUMP AS FIELD BASED ASSESSMENT

The countermovement jump (CMJ) is a commonly utilized test in team and individual sport to evaluate lower extremity functional performance, monitor fluctuations in athlete readiness, and dose-response to training and competitive stress. [5,6] The CMJ is a time efficient, non-fatiguing assessment of the stretch shortening cycle (SCC) that practically, affords the ability for frequent testing in team settings. More specifically, it is a measure of the slow stretch shortening cycle. The slow-SCC, characterized by a contraction time greater than 250 milliseconds has been associated with longer ground contact times found in the acceleration phase of sprinting.[7,8] Given the constraints (e.g., court dimensions) and general demands of basketball requiring frequent changes in intensity of movement and locomotor patterns (i.e., walking, running, jumping, change of direction, etc.) the capacity to exhibit accelerative abilities is a key determinant in task (e.g., transition from offense to defense, closing out, rebounding, etc.) completion specific to the sport.[9–11] Broadly, the research on the CMJ has produced strong evidence showing a relationship between key bio-motor and locomotion abilities (sprinting, jumping, change of direction) necessary for sport.[7,12] More importantly, this suggests the CMJ may be a more relevant tool for assessing NMP in basketball in comparison to other field-based test (e.g., drop jump) related to the fast SSC (<250 milliseconds).

In general, locomotion is characterized by utilization of the SSC in which pre-activation precedes an active braking phase where the muscle is stretched eccentrically. This eccentric loading increases the storage of elastic energy which ultimately is used during the concentric action or shortening of the muscle. Mechanically, the shortening of the muscle facilitates push-off and displacement of center of mass (COM) (Komi et al. 2000, Nicol et al., 2006). Hence, the SSC is propagated using elastic properties of muscle which store energy during eccentric actions and utilizes this energy during concentric actions to increase force and power output.[2,13]

Traditionally, gross output variables (i.e jump height, force, power, etc.) of the CMJ have been the primary measures of interest. Given the concentric and eccentric nature of the SSC more contemporary research has shown the value of investigating alternative variables to elucidate greater insight into the changes in neuromuscular performance and the phase-oriented force-time characteristics that can be obtained through analysis of the CMJ utilizing force platforms.[14,15] The evaluation beyond traditional CMJ variables may allow practitioners and researchers to glean greater understanding into changes in NMP and the underpinning mechanisms specific to force-time phase analyses. For example, changes in Flight Time:Contraction Time (FT:CT) have been suggested to be indicative of low frequency fatigue in previous literature.[16]

The common use of the CMJ in practical and lab-based settings is centered in its reliability. Previous research has shown the CMJ to exhibit consistently high inter and intraday reliability.[6,14,17,18] Moreover, the use of the CMJ has evolved since the early use of best trial measures. Contemporary use of the CMJ is centered on the analysis of variable averages across trials based on increases found in reliability and sensitivity in detecting performance changes.[5,19–21] The use of the CMJ to evaluate acute readiness and the process of physical preparation exhibits high levels of utility in monitoring athletes in sport and warrants continued research in lab-based and applied settings given the practical ability to conduct testing.

SECTION III: ATHLETE MONITORING

Athlete monitoring strategies have become prevalent in team and individual sports as there has been an increasing demand on performance and medical personnel to quantify, analyze, and understand imposed stress, dose-response, performance related outcomes, and injury risk. The advancement of technology has provided practitioners and clinicians the ability to acquire training data more efficiently from training and competition-based exposures. The abundance of these data can be utilized to inform the construction and process of preparation for sport participation as well as provide insights into an athlete's status specific to the recovery-adaptation, injury risk, and return to play (e.g., stages of rehabilitation).[22–25]

Athlete monitoring can be described as the practice of collecting repeated measures in athletics to quantify physical and psychological-related training load with the objective to optimize readiness for competition. Training load can be defined as the cumulative amount of stress placed on an athlete from multiple training sessions and competitive events over a longitudinal period.[22,24,26] Specifically, monitoring external training load (eTL) refers to the assessment of mechanical or locomotive work completed by an athlete.[6,24,27,28] In sport, eTL is the objective measure of work incurred by the athlete during competitions or training exposures. Moreover, eTL is the input variable in a training system that coaches and scientists most commonly manipulate to elicit the desired training response.[29]

In basketball, monitoring eTL dates to the 1938-39 Big Ten basketball conference season and the use of a novel electronic tracing apparatus.[30] Current monitoring of eTL in basketball has evolved from time-motion analysis to quantification via accelerometers, video analysis, and local position systems (LPS). Practically, LPS for indoor sports may be cost prohibitive due to high costs associated with infrastructure changes to existing buildings and arenas. The lack of portability also presents challenges in data collection away from homesite facilities. Hence, the development of alternative eTL monitor strategies for indoor sports have been implemented around the use of accelerometers to quantify mechanical stress.[31–33]

The use of inertial measurement units (IMUs) provides a practical option to measure eTL in basketball. Typically, athletes wear IMU microsensors in special garments designed to secure the unit between the scapulae or at the waist. Commercially available IMU microsensors include an accelerometer, a gyroscope, and a magnetometer.[33,34] The three components of the microsensor can capture the dynamic movement signature of an athlete during sport participation. Accelerometers measure magnitude and frequency of linear acceleration in G-Forces. Gyroscopes are motion sensing devices that measure angular velocity and orientation. Magnetometers are utilized to enhance orientation in respect to magnetic north.[35] Additionally, built-in microprocessors allow for supportive software to apply specific algorithms to transform raw inertial data into standardized variables to serve as proxy output variables for eTL.

PlayerLoad™ (Catapult Innovations, Melbourne, VIC, Australia) is a commonly used metric to quantify whole-body movement. The variable PlayerLoad™ is a vector of magnitude, expressed as the square root of the sum of the squared instantaneous rate of change in acceleration in each of the 3 orthogonal planes divided by the scaling factor of 100 and is expressed in arbitrary unit (AU).[27,28,36] PlayerLoad™ can be mathematically represented with the following formula:

$$PlayerLoad^{TM} = \sqrt{\frac{(a_{y1} - a_{y-1})^2 + (a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})^2}{100}}$$

Note: a_{y1} = anteroposterior acceleration; a_{x1} = anteroposterior acceleration; a_{z1} = anteroposterior acceleration.

PL has been primarily utilized as a measure of volume with previous literature finding a near perfect correlation between total distance and PL over the course of practice exposures in collegiate basketball.[28] Furthermore, PL has previously been utilized to evaluate relationships between eTL and changes in NMP in collegiate basketball players with increases in volume eliciting decreases in FT:CT and RSImod in the CMJ 24 hours post training exposure.[28] These findings suggest there is a parallel relationship between increases in eTL and subsequent changes in NMP. However, eTL in isolation may not explain changes in NMP, hence further investigation is warranted in basketball to uncover additional factors that may influence NMP.

SECTION IV: SLEEP, ATHLETES, WEARABLES, AND PERFORMANCE

Quantity and quality of sleep have been associated with health outcomes. In general, the literature suggests gradual decreases in sleep duration from birth to adulthood. The literature related to sleep recommends 7 to 9 hours of sleep for adults and 8 to 10 hours for adolescents.[37] It must be noted that illness, sleep-debt, physiological status, psychological stress, and other lifestyle related factors may contribute to the variance in individual sleep needs from day to day. The daily demands of college athletes differ greatly from the general population. Most days consist of multiple exposures to physical stress in the form of practice or physical preparation-oriented sessions in addition to the demands of academics and social engagement. Research has found that the amount of sleep an athlete obtains is highly dependent on their training schedule with early morning starts contributing to pre-training fatigue.[38]

Athletes have been shown to sleep less than 8 hours, with 11% reported to sleep less than 6 hours, with worse sleep quality prior to competitions.[39,40] In addition to reduced duration of sleep, poor sleep quality was observed in 38% to 57% of elite athletes.[41] Cultural norms, lifestyle demands, acute training loads and athletes exhibiting poor self-assessment of sleeps needs, duration and quality of sleep may also contribute to current sleep patterns observed in athlete populations.[42,43] In team sport, travel specifically poses challenges to sleep and performance via alterations in sleep patterns and disturbances in circadian rhythms.

Sleep and athletic performance has been well investigated across many sports. [37,44] In basketball specifically, collegiate student-athletes with self-reported increases in sleep extension compared to baseline demonstrated faster timed sprints, shooting percentage increases in free throw and 3-point shots as well as ratings of physical and mental well-being.[45] Additionally, research on sleep and basketball performance have identified three central themes to consider practically: (1) sleep extension and quality of sleep are associated with better performance and lower injury risk. (2) higher training load has an impact on subsequent sleep (3) and circadian rhythm are impacted by travel and game scheduling as well as win-loss outcomes.[46,47]

Wearable technology now allows practitioners to move away from self-reported measures and accurately monitor sleep outside of gold standard lab settings (i.e., polysomnography). Consumer grade sleep trackers now provide 94%-96% accuracy for 2-stage sleep detection (sleep, wake) utilizing accelerometer-based models.[48] Models for 4-stage detection (REM, Deep, Light) have not yet reached levels of accuracy (57%-79%) to necessary broad use in applied settings. Despite limitations in measuring quality of sleep the accuracy of current models to measure sleep duration allow for large scale research studies and the use of sleep data to practically manage the training process in sport. Further research is warranted to investigate the association between sleep, physiological readiness, and performance outcomes.

SECTION V: RECOVERY AND PERFORMANCE

The ability of athletes to cope with training stressors may potentially be the difference in athlete availability, physical readiness, and competitive outcomes. Recovery broadly, can be defined as the compensation of deficit states of an organism or the whole set of processes that result in an athletes renewed ability to meet or exceed a previous performance.[49,50] Moreover, in sport, recovery can also be defined by the period of time necessary for modified physiological parameters to return to resting values.[51] In team sport that ability to expedite recovery between training session and practice are critical to outcomes. In basketball, game schedule congestion can significantly increase the workloads in which athletes have to recovery between competitions.[52] This poses a challenge for medical and performance personnel to facilitate game readiness on a weekly basis. In collegiate athletics including basketball, previous research investigating recovery attitudes towards sleep, nutrition, cold water emersion, and compression were perceived as the most effective recovery modalities.[53]

Recently the commercialization of "recovery" has led to the proliferation of varying products for expediting recovery from training-induced or general fatigue. Many of these products have limited evidence supporting the efficacy of their use in athletics. The utility of many of these modalities have come from use in medical settings that range from psychological treatment to prevention of coagulant related issues. Despite the limitation in empirical evidence supporting use in athletics many of these tools can be found in the facilities of collegiate and profession teams as well as settings for home use. Hence, more scientific research is warranted to justify the continued acquisition of these recovery tools and their practical use of these interventions.

Flotation Restricted Environmental Stimulation Therapy (Flotation-REST) is a non-pharmacological form of therapy that involves floating in a shallow pool (quiet and dark) of water saturated Epsom salt and heated to approximately 35-degrees Celsius. The high buoyancy of the solution allows an individual to float comfortably without effort. The aim of treatment is to reduce environmental stimuli such as light, sound, and touch.[54] Floatation-REST is contraindicated for individuals with claustrophobia, epilepsy, open wounds, or other contagious disease.

The early studies investigating in Floatation-REST were conducted in the 1970s and were primarily concerned with treating a variety of mental health conditions, including post-traumatic stress disorder, obsessive-compulsive disorder, and panic disorder.[54] Numerous studies have been conducted to evaluate its efficacy. Many studies have reported results exhibiting effectiveness in reducing stress, anxiety, and depression, as well as improving mood and relaxation.[55–57] Additional findings also suggest benefits in reducing pain, improving sleep, and increasing creativity. Overall, the literature suggests that Floatation-REST may be an effective complementary form of therapy for reducing stress, anxiety, and depression, as well as improving mood and relaxation. These data, however, should be interpretated and generalized with caution.

In athletics, there is limited research investigating Floatation-REST. The literature utilizing Floatation-REST in sport settings have found the treatment to significantly attenuate muscle soreness, modify neuroendocrine signaling, and improve mood immediately after strength training in male athletes[58] Additionally, Floatation-REST was found to significantly enhance mood and lower perceived muscle soreness in male and female elite Australian athletes from multiple sports who had not experienced the intervention previously.[59] This is in agreement with previous literature investigating associations in mental health populations. These findings would suggest generalizability of Floatation-REST to athletic populations for use as a recovery modality. Future research should seek to investigate the effects of Floatation-REST in athletics while addressing concerns associated with earlier research (e.g., sample size, longer follow-up, comparator, etc). Future research should also seek to account and control for factors (e.g., external training load, psychological stress, etc.) that may confound the effectiveness of an intervention such as Floatation-REST that seeks to manipulate the autonomic nervous system.

Peristaltic Pulse Dynamic Compression (PPDC) therapy has gained attention as a recovery treatment. PPDC is an artificial process of rhythmic applications of circumferential pressures to a limb in a peristaltic (i.e., sequential compression) manner in a distal to proximal direction. The technology is normally used to promote blood flow and remove waste products from patients suffering from lymphedema and for athlete recovery.[60] It has been widely used in the medical setting, however, in recent years the commercialization of compression has expanded its application to the team sport due to the purported benefits it offers in terms of muscle recovery, blood circulation, and performance enhancement.

The use of PPDC, broadly is centered on using inflation (60-110 mm Hg) as a pressure gradient to increase lymphatic circulation, venous return, and tissue osmotic pressure.[60,61] There are several models for application of PPDC with limited scientific evidence to support treatment strategies in sport. Previous literature has produced conflicting evidence in support of PPDC as a recovery modality. PPDC demonstrated promise in enhancing acute range of motion with less discomfort in female dancers.[60] Additionally, 15 minutes of PPDC improved pressure-to-pain threshold as measure of exercise induced muscle trauma compared to a control treatment in male and female Olympic training center athletes.[62] In contrast, PPDC did not significantly alter the rate of muscle glycogen resynthesis and blood lactate clearance in male athletes after cycling protocols.[61,63] These findings suggest the positive effects observed in the literature are mainly perceptual with limited physiological benefits found in biomarkers.

Despite the common use of PPDC in basketball specifically there is a paucity of research investigating the efficacy of its use practically and effects on recovery at the neuromuscular level. Given the common use as a recovery modality there is a need to understand the effects of PPDC in modifying training induced fatigue. Hence, studying PPDC and NMP may provide greater insight into how this treatment may impact peripheral fatigue and the contractile capacities that can be measured via NMP assessments such as the CMJ.

SECTION III: SELF-REPORTED MEASURES

Understanding an athlete's level of perceived recovery and stress is critical in the optimization of readiness for training and competition. In applied settings a valid and reliable, yet practical, self -report instrument is needed to assist practitioners in making informed decisions related to training content and construct. The short recovery stress scale (SRSS) was developed to address these needs in team sport. It consists of 8 questions The SRSS has been found to demonstrate adequate levels of reliability and validity across different sports suggesting it can be utilized effectively with a multitude of court and field-based sports and in different languages.[50,64,65] The SRSS has also exhibited correlation with other previously validated measures evaluating recovery (e.g., REST-Q).[65]

Researchers have utilized the SRSS to investigate the effects of training load, competition, travel, and psychological factors on athlete recovery, stress, and injury.[66,67] Practically, the literature suggests that serial use of the SRSS exhibits utility as a tool to identify increases in general stress which may aid in proper mobilization of key stakeholder for interventions and or auto-regulation of training. Despite its strong psychometric properties and ease of application in team settings it may be limited in the scope in which it captures stress and recovery related data. Like many self-reported measures, it is subject to bias and participant interpretation. Further, it does not capture other ecological stressors frequently imposed on athlete populations. Specifically, there is a need to further quantify and research other specific psychologically related domains of stress in collegiate athlete populations.

Collegiate students, including athletes, face numerous psychological challenges including stress, anxiety, and depression. The Center for the Study of Collegiate Mental Health (CCMH) is a multi-disciplinary group of mental health professionals working with and on behalf of university students throughout the U.S to provide support and intervention. It was originally formed to create a large-scale database to monitor mental health, conduct research, and guide clinical practice in college-age students.[68,69] This collaboration produced the Counseling Center Assessment of Psychological Symptoms-70 as a screening instrument designed to capture the most prevalent psychological concerns in the college student population.[69] Following initial analyses, the evolution of a 62-item instrument was created based on limitations in clinical interpretability, cross-loading issues, and vague items.[69]

The CCAPS has been shown to exhibit high levels of practicality. It is easily administered, scored, and can be used free of charge in either short (34-item) or long (62-item) form. Despite its increasing popularity in clinical, the number of studies investigating the CCAPS' psychometric properties and its clinical viability within its target population remains relatively small.[68,69] There is even less investigation of the CCAPS in collegiate athletics despite a high level of ecological validity. Previous use of the CCAPS use in athletics is limited to the CCAPS screen as a pre-participation evaluation.[70]

The CCAPS-34 was released in September 2009 and updated in 2012. It is a 34-item instrument with seven distinct subscales that are related to psychological symptoms and distress in college students and incorporates the Distress Index. The sub-scales are academic distress, depression, frustration/anger, eating concerns, generalized anxiety, and social anxiety and the instrument takes approximately 2-3 minutes to complete.[68] Given its brevity it can be used as a brief assessment instrument at any point in treatment for repeated measurements. Despite the intended use of the CCAPS-34 as clinical assessment tool psychologist it may also be of use to medical and performance staff to glean greater understanding of the effects of psychological stressors common place in today's ecological landscape.

SUMMARY

The use of the CMJ as an assessment of NMP in athlete monitoring strategies provides a tool to track training load induced changes in fatigue and adaptive responses across a period of preparation or competition. The analysis of CMJ variables has demonstrated an ability to detect changes in neuromuscular status which may aid practitioners in decisions related to periodization and use of interventions to better facilitate readiness for competition. Despite a growing body of research investigating NMP and eTL variables, there is limited research examining changes in CMJ performance and ecological variables such as sleep, recovery practices, and psychological factors. These ecologically related variables present sport coaches and support staff (e.g., medical and performance) challenges to clear insights of dose-response relationships of sport-specific training stress. Additionally, these factors represent confounding variables for scientists attempting to understand comprehensive mechanisms of readiness and fatigue in sport.

Previously literature has focused on establishing relationship between NMP and eTL without accounting for other stressors. Foundationally, this research was warranted to first comprehend the demands of basketball and identify the modifiable variables (e.g., training volume and intensity) that constitute training plans and periodization broadly. Increases in volume (e.g., PlayerLoad) and intensity (e.g., PlayerLoad per minute) in basketball appear to elicit corresponding changes in NMP variables. In general, it appears that athletes exhibit an ability to maintain output (i.e., Jump height) with accompanying alterations in strategy-related variables (i.e., FT:CT, RSImod, and countermovement depth). These finding however, are limited to associations with eTL which do not account for other stressors that may impact physiological readiness. To glean greater understanding of the complexities of team sport in the real world it may be more efficacious to evaluate responses to ecologically related stressors in addition to eTL, as basketball players and college athletes in general endure a multitude of stressors outside of those imposed by the demands of playing a sport in isolation.

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Appendix C

ADDITIONAL METHODS

1. TABLE C1 – SUMMARY OF PROTOCOL PROCEDURES

I. Institutional Review Board Documents
II. Neuromuscular Performance Measures
    A. Countermovement Jump
III. External Training Load Measures
IV. Shooting Accuracy Measures
V. Sleep Measures
VI. Athlete Self-Report Measures
    A. Short Recovery and Stress Scales
    B. CCAPS-34

Human Research Protection Program
Institutional Review Board for Social & Behavioral Sciences
iProtocol

Current User: **Curtis, Michael (mac5s)**

Protocol Number: 4812

IRB of Record: UVA

Title: Athlete Monitoring in Collegiate Basketball

Descriptive Title: broad consent protocol for prospective collection of athlete monitoring data in collegiate basketball

Previous IRB-SBS Protocol Number:

Date Approved: **2023-01-30**

Continuation Required On: **2024-01-30**

This protocol record was electronically approved on 2023-01-30

This protocol record is currently Approved.

Personnel (UVA Only)

Principal Investigator: Hertel, Jay (jnh7g) - Status: Faculty
Department: E1:CU-Kinesiology, E0:CU-Kinesiology
Title: E1:Faculty Wage-8, E0:Joe Gieck Professor in Sports Medicine & Professor
CITI Training:
2021-03-19 - Conflicts of Interest - Stage 1
2017-03-02 - Conflicts of Interest - Stage 1
2023-03-07 - GCP for Clinical Trials with Investigational Drugs and Medical Devices (U.S. FDA Focus)
2022-07-07 - IRB-HSR RESEARCHER BASIC COURSE
2019-07-11 - IRB-HSR RESEARCHER BASIC COURSE
2016-07-22 - IRB-HSR RESEARCHER BASIC COURSE
2022-02-22 - Undue Foreign Influence: Risks and Mitigations

Contact Person: Goss, Dante (nxq9uz)

Research Team (Sub-Investigators):

Curtis, Michael (mac5s)
Department: E2:AT-Basketball-Men's, E1:AT-Basketball-Men's, E0:AT-Basketball-Men's, U1:Education Graduate
Title: E2:Assistant Coach, Men's Basketball-5, E1:Assistant Coach, Men's Basketball-4, E0:Head Strength & Conditioning Coach, Men's Basketball
CITI Training:
2022-01-31 - IRB-HSR RESEARCHER REFRESHER COURSE
2019-02-22 - IRB-HSR RESEARCHER REFRESHER COURSE

Holt, Jeffrey (jjh2b)
Department: E4:PV-Summer & Spec Acad Progs, E3:AS-Statistics, E2:PV-Ctr for Liberal Arts, E1:PV-International Studies, E0:AS-Statistics
Title: E4:Unit Paid Employee (Faculty), E3:Unit Paid Employee (Faculty), E2:Unit Paid Employee (Faculty), E1:Unit Paid Employee (Faculty), E0:Professor of Mathematics and Statistics, General Faculty
CITI Training:
2020-02-17 - Conflicts of Interest - Stage 1
2021-11-01 - IRB-SBS RESEARCHER BASIC COURSE-NO PRISONERS
2010-12-14 - IRB-SBS RESEARCHER BASIC COURSE-NO PRISONERS
2021-11-30 - Undue Foreign Influence: Risks and Mitigations

Kramer, Natalie (nak5dy)
Department: E1:CU-Kinesiology, S2:CU-Kinesiology, S1:CU-Kinesiology, S0:CU-Kinesiology, U1:Education Graduate
Title: E1:Faculty Wage-6, S2:GTA-A-5, S1:GTA-A-3, S0:Graduate Student Worker
CITI Training:
2022-05-05 - Conflicts of Interest - Stage 1
2021-08-09 - IRB-HSR RESEARCHER BASIC COURSE
2018-08-30 - IRB-HSR RESEARCHER BASIC COURSE
2011-07-02 - IRB-HSR RESEARCHER BASIC COURSE
2022-05-05 - Undue Foreign Influence: Risks and Mitigations

Rodu, Jordan (jsr6q)
Department: E1:AS-Statistics, E0:AS-Statistics
Title: E1:Unit Paid Employee (Faculty), E0:Assistant Professor
CITI Training:
2021-12-02 - Conflicts of Interest - Stage 1
2018-04-23 - IRB-HSR RESEARCHER BASIC COURSE
2020-08-31 - IRB-SBS RESEARCHER BASIC COURSE-NO PRISONERS
2017-12-20 - IRB-SBS RESEARCHER BASIC COURSE-NO PRISONERS

Westbrook, Justin (jw3rh)
Department: S0:AT-Basketball-Men's, U1:Education Graduate
Title: S0:Student Assistant, Strength and Conditioning
CITI Training:
2018-11-04 - Biomedical Responsible Conduct of Research
2022-01-19 - IRB-HSR RESEARCHER BASIC COURSE
2018-11-04 - IRB-HSR RESEARCHER BASIC COURSE
2018-11-04 - IRB-SBS RESEARCHER BASIC COURSE-NO PRISONERS

Department Chair: Bradshaw, Catherine (cpb8g)

non-UVA Research Team (Sub-Investigators)

non-UVA Engaged Institutions (in the United States)

Use this section for non-UVA Institutions which are located in the United States.

Use the International Research section, farther down this page, for non-UVA Institutions located outside of the United States.

Is more than one institution located in the United States (another university, commercial institution, etc.) engaged in this research proposal? No

Study Overview

Anticipated end date for collecting data: 2025-05-31

Anticipated end date for analyzing data: 2025-12-31

Is this research funded? No

What is the purpose in conducting this research? How does this study contribute to the advancement of knowledge and why is it worth doing?

The concept of athlete monitoring has grown across all sporting domains in the past decade. Broadly, athlete monitoring, encompasses both objective and subjective measures to chart workload, injury, wellness, and performance. These metrics, either individually or combined, are used to guide changes in programming in hopes of optimizing athletic performance and reducing injuries.

This data is collected within a practical sporting context, usually by sports performance and sports medicine staffs. As this field continues to grow and technology becomes more pervasive, it is important to apply a research lens to the data and to better understand each technology and explore how the different technologies interact to signal improvement or decrements in athlete health. By doing this, researchers are supporting the practitioners who are directly involved in athlete care and athletes by ensuring technologies employed are to the benefit of the athlete.

Currently, very few investigators are analyzing all domains of athlete monitoring in singular models The purpose of this study is to prospectively collect data and answer questions related to injury risk, fatigue, sports performance optimization, and mental well-being.

What will participants do in this study? Please provide an overall summary of the study plan. Where and when it will be conducted? What do you hope to learn from these activities? If the study has more than one phase, clearly map out the different phases. You will be required to describe the study components in more detail in later sections but use this paragraph to help your IRB reviewer to understand the general outline of the study. Other sections in the protocol form can be seen below.

As part of routine team activities, basketball athletes have their training protocols and psychological wellness monitored on a regular basis. The aim of this study is to prospectively track this data to identify interventions to aid in optimizing athlete welfare and sports performance. Much of this data is being analyzed retrospectively under IRB SBS protocol #2217. By moving to a broad consent protocol, as researchers, we aim to enhance data collection and ensure that the routine data is collected systematically and lends to robust statistical analysis. Secondly, with consenting, athletes will have a greater understanding of how their data is being used to benefit themselves, the team, and future athletes. All data is collected within the University of Virginia athletics department.

As the landscape of athlete monitoring and athletics changes, instruments with no prior data collection may be added this protocol. The modification of this protocol to include the the psychological survey, CCAPS-34, is the first example of this. The addition of a specific psychological survey is being requested due to increased awareness of how ecological stresses can impact sport and vice versa. Understanding how and when during different timepoints in the year these stressors arise or are related can help practitioners with delivering more specific and just-in-time care. As the landscape of athlete monitoring and athletics changes, instruments with no prior data collection may be added this protocol. The modification of this protocol to include the the psychological survey, CCAPS-34, is the first example of this.

Athletics has approved the use of all instruments outlined in this protocol.

Is this study topic relevant to cancer risk factors, prevention, cancer treatment, or survivorship (e.g., pain, financial toxicity, etc.), or will the study purposefully include participants currently or previously diagnosed with cancer, or their caregivers?
No

(optional) **Study Overview file upload**: Below you have the option to upload additional files to help the Board better understand your study. You are not required to provide any additional explanation beyond completing the text boxes provided in this Study Overview section; however, for example, if you are using a new technology or a complicated process that would be more easily demonstrated with an image or video, you can upload the file here.

Participant Groups

Participant Group Name: Basketball

Age Range (years): 18-30

Vulnerable populations: includes students

Maximum number of participants, in this group, expected to enroll over the life of the study: 60

Minimum number of participants, in this group, expected to enroll over the life of the study: *(required)*

Total number of participants, in this group, ever enrolled: 14

Approximate number of participants, in this group, currently enrolled: 14

Future Enrollment: We will enroll participants, in this group, during the next twelve months

Approximate number of participants, in this group, expected to enroll in the next twelve months: 30

Have participants, in this group, withdrawn from the study in the past year? No

Describe the participants in this group.

Sex: Males and Females
Race: All races will be eligible to participate

1. Inclusion Criteria
All student-athletes, defined as students enrolled at University of Virginia who participate in men's or women's varsity basketball will be included in the current study.

2. List the criteria for exclusion
Student-athletes not currently participating on the basketball team.

Will participants in this group be *compensated* for taking part in your study? No

Participant Summary

Participant Group Name: Basketball

Maximum number of participants, in this group, expected to enroll over the life of the study: 60

What special experience or knowledge does the Principal Investigator, Faculty Sponsor, and the Research Team (Sub-Investigators) have that will allow them to work productively and respectfully with the participants in this protocol and/or participant data?

Michael Curtis (strength and conditioning coach) is directly involved with day-to-day care of the athletic teams and has research experience. Additionally, both Dr. Hertel and Natalie Kramer Kupperman are Certified Athletic Trainers with experience working in elite athletics with both the athletes and staff and have the resources and training for the statistical analysis. Drs. Rodu and Holt are experts in statistical analysis in sport and are uniquely qualified to handle the data generated in the athlete monitoring field.

What is the relationship between the participants of this study, and the Principal Investigator, Faculty Sponsor, and the Research Team (Sub-Investigators)? Does the Principal Investigator, Faculty Sponsor, or the Research Team (Sub-Investigators) know any of the participants personally or hold any position of authority over the participants (including but not limited to: grading authority, professional authority, etc.)? Do any of the researchers listed on the protocol stand to gain financially from any aspect of this research?

The role of Michael Curtis as the strength and conditioning coach and facilitator of the athlete monitoring program does not allow for him to be omitted from the study. His primary role as a strength and conditioning coach per NCAA and athletic department policy do not allow him to provide sensitive or specific health data (e.g., bodyweight, strength testing, speed testing, etc.) information to the sport coaches outside of general physical readiness. As a researcher his role is to educate participants and provide informed consent so that student-athletes understand the information and data collected is to be solely utilized to optimize physical readiness and decrease the risk of sport-related injury, as well as advance "in-situ" research in athletics. It has no impact on playing status or medical care.

None of the researchers stand to gain financially for this research.

Recruitment & Consent

How will participants be approached or contacted for recruitment into the study?

The majority of data being collected in this study is data which is being collected by the team for routine welfare and performance monitoring. Regardless of researcher involvement the team will undertake their routine monitoring program. At the start of researcher involvement (i.e. once this protocol is approved) and then as needed as new athletes join the team (typically on a yearly basis), a meeting will be set up and athletes will be invited to attend in which time the study protocol will be explained to the athletes. Athletes can ask questions in the group setting during the meeting. Additional questions and consenting will occur during a one-on-one meeting with a member of the research team (excluding Michael Curtis) to ensure all questions are answered thoroughly and the athlete has appropriate time to read the consent document.

The recent modification introduces a survey instrument not previously collected on the team. Upon approval of the modification, athletes will re-consent into the study. Along with talking through all data collected, researchers will make special note of the psychological survey to potential participants.

Do participants have any limitations on their ability to *consent* ? No

Describe the limitations on their ability to consent:

What are the consent processes for this study?

A member of the research team will present the consent information in both a group setting and in an individual meeting with the athlete. If willing, participants will sign their consents in Docusign. They will be given a printed version of the consent and also emailed their signed copy for their records. Electronically signed consents will be saved to the secure ES3 server maintained by the UVA School of Education.

Upon of approval of the recent modification, participants will re-consent using the previously stated process. The consent has been updated to include the CCAPS-34 as a data collection instrument. If current participants wish to remain a part of the original study do not consent to the CCAPS-34 instrument, they will not be re-consented. Their original consent will be maintained and their data, excluding the CCAPS, will be used in line this protocol. Not consenting to the CCAPS-34 instrument will not have any impact on team status, playing status, medical care, or coaching. Athlete will be made aware of this during the consenting process.

Participants are not unable or unwilling to document their consent.

Will participants be deceived and/or have information withheld from them about the study? No

Will participants be debriefed? No

Recruitment & Consent Tools

Consent or Assent (signature required)
View File: consent_document14.docx
date uploaded: 2023-01-27, by: Kramer, Natalie *(nak5dy)*
This file is approved.
date approved: 2023-01-30

Associate Recruitment & Consent Tools with Participant Groups

No requirements.

Data Sources

Data Source Name: Anthropometrics

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

These data are collected on semi-regular intervals. The items are:

Height
Weight
Wingspan
Hand length

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

Why is it necessary for you to retain participant identifiers? Will the identifiers be connected to the data or kept separate for contact purposes only?

This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: Athlete Availability Status

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

These data are collected on training and game days. Availability is a measure of an athlete's status to participate in sports on a given day. Below is the scale utilized.

1 - Fully available
2 - Available but with modification
3 - Only available for major competition
4 - Not available

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

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This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: CCAPS-34

When will the data be collected? Data will be collected after IRB-SBS approval of this protocol.

Who will collect the data? Primary data source

Describe this Data Source.

These data are psychological stress scores collected through a 34-item instruments with seven distinct subscales that are related to psychological symptoms and distress in college students and incorporates the distress index. The instrument takes approximately 2-3 minutes to complete and can be used for repeated measurements for screening or clinical treatment. This a validated instrument and has been utilized in collegiate athlete screening and monitoring. The 34 items are all on a 0–4-point scale. An example is uploaded in the "Instruments" section of this protocol.

The subscales are:
1. Depression
The depression subscale of the CCAPS-34 captures feelings of isolation, worthlessness, lack of enjoyment and hope, sadness, and suicidal ideation.

2. Generalized Anxiety
The generalized Anxiety subscale of the CCAPS-34 contains questions that assess for racing thoughts, sleep difficulties, tension, racing heart, and panic attacks or fear of panic attacks.

3. Social Anxiety
The social anxiety subscale of the CCAPS-34 contains questions aimed at assessing shyness, ability to make friends easily, self-consciousness, and feeling discomfort around people.

4. Academic Distress
The academic distress subscale of the CCAPS-34 focuses on academic confidence, motivation, enjoyment, and concentration. It is important to keep in mind that high-performing students can experience high levels of academic distress while low-performing students may deny academic distress.

5. Eating Concerns
The eating concerns subscale of the CCAPS-34 consists of questions that focus on preoccupation with food, worry about eating too much, and feeling a lack of control when eating. The Eating Concerns subscale does not ask about weight gain and/or loss, excessive exercise, fear of weight gain, amenorrhea, overeating during discrete time periods, or the chronicity of behavior.

6. Frustration/Anger
The frustration/anger subscale of the CCAPS-34 captures difficulty controlling temper, thoughts of hurting others, fear of acting out violently, frequently getting into arguments, feeling easily angered, and the desire to break things. The CCAPS-62 also assesses for irritability. A high score on this scale does not necessarily mean that a client is dangerous or aggressive. Rather, high scores represent high levels of frustration, anger, suppressed feelings, and difficulty managing emotions or reactions.

7. Substance Use
The substance Use subscale of the CCAPS-34 assesses only for alcohol use and does not contain any questions pertaining to drug use.

Athletes will be familiarized with these items at the beginning of the data collection and instructed on the meaning of endorsed items. As with the rest of the protocol, student-athletes will be informed that participation is voluntary and there are no consequences for individuals who choose not to participate. Student-Athletes will also be informed that they may also choose to connect with sport medicine or sport psychology staff at any time if completion of this questionnaire brings up thoughts that are distressing.

The instrument will be collected once a week through a HIPPAA compliant, University-approved data collection system called Smartabase. The software uses an iPad to collect survey resposes. A member of the athletics medical staff who is a confidential employee, and trained in responding to mental health crisis will be present for collection and review each survey for concerning responses upon completion by the student-athlete. In addition to the manual review, a flagging system has been built into the collection software (Smartabase) which will send alerts to pertinent athletics medical staff automatically.

There are 3 critical items that will require an immediate medical follow-up in the event of any score above 0.
I have thoughts of ending my life (#25)
I am afraid I may lose control and act violently #29)
I have thoughts of hurting others (#34)

Critical item entries endorsed by student-athletes will be immediately and directly addressed with the student-athlete by medical staff in accordance with athletic department/team policy and procedures. These procedures include an immediate evaluation with a sports psychologist and having the athlete placed on a medical leave. If the medical staff members detects an immediate and present danger to the responding athlete or other members of the team, 911 will be called.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name will be included with data. This is necessary to link longitudinal data of other variables of interest together. Only researchers on the protocol will have access to data with names associated to data.

Why is it necessary for you to retain participant identifiers? Will the identifiers be connected to the data or kept separate for contact purposes only?

This is necessary to link longitudinal data together as well as other variables of interest from separate data sources. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: Exposure Type

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

These data are collected on a daily basis. Exposure type creates a record of the team activity for the day. Below are the exposure type options

Strength Only Exposure
Practice Only Exposure
Strength Followed by Practice Exposure
Strength Followed by Game Exposure
ESD Only Exposure
ESD Followed by Practice Exposure
Practice Followed by Strength Exposure
Game Only Exposure
Game Followed by Strength by Exposure
Strength, Practice, Followed by Game Exposure
Active Recovery
Absolute Recovery

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

Why is it necessary for you to retain participant identifiers? Will the identifiers be connected to the data or kept separate for contact purposes only?

This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: Force Plates

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

These are dual force plates used for the measurement of ground reaction forces during jumping or weightlifting movements. Within the routine team monitoring, these instruments are used to assess neuromuscular fatigue and movement strategies. Examples of metrics collected:

Jump height
Peak force
Asymmetries
Max velocity
Acceleration
Rate of force development.

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

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Data Source Name: Functional Movement Assessment

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

DARI Motion is an 8-camera motion analysis system that captures functional movement assessments. Within the routine team monitoring, practitioners use this device to create individualized plans to improve movement quality. The system captures:

joint range of motion
sway
alignment
mobility

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

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Data Source Name: Isometric Hip and Thigh Strength

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

Strength is assessed through dual load cells designed to measure isometric hip and thigh strength. Within the routine team monitoring, these instruments are used to assess muscular fatigue. Variables include:

Peak force output

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

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This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: On-Court Workload

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

Catapult Sports is a wearable device equipped with an accelerometer that is routinely worn for conditioning, practice, and games. This data gives information about the amount of workload endured by the athlete during training or games. Metrics collected by this device include:

Duration
Accelerations
Distance
Load
Velocity
Change of direction

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

Why is it necessary for you to retain participant identifiers? Will the identifiers be connected to the data or kept separate for contact purposes only?

This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: Rating of Perceived Exertion (RPE)

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

These data are collected on training and game days. RPE is a subjective rating given by the athlete on how hard they felt they worked during the session. The rating is given on a 10 point scale consistent with the Borg-10.

0 - Rest
1 - Really easy
2 - Easy
3 - Moderate
4 - Sort of hard
5 - Hard
6 - Hard
7 - Really hard
8 - Really hard
9 - Really, really hard
10 - Maximal

Athletes are familiarized with this scale at the beginning of the season.

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

Why is it necessary for you to retain participant identifiers? Will the identifiers be connected to the data or kept separate for contact purposes only?

This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: Sleep Tracking

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

The instrument used to quantify sleep is the Oura ring. It uses sensors like accelerometers, thermometers, and infrared to measure physiological variables. Variables include:

Time asleep
Heart rate
Heart rate variability
Respiration rate
Temperature deviation

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

Why is it necessary for you to retain participant identifiers? Will the identifiers be connected to the data or kept separate for contact purposes only?

This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: Sprint Analysis

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

1080 Sprint is a testing device used to measure to the speed and power of athletes during running. The device fits hooks around the athlete’s hips while sprinting. The typical test is a 30 meter sprint. Variables are:

acceleration
velocity
force production

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

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This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: Velocity Based Training Quantification

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

To track barbell velocity during weight room exercises a camera-based system called Perch is utilized. This allows practitioners to understand the intensity of the weight room workout. Metrics collected: Tonnage Velocity   This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

Why is it necessary for you to retain participant identifiers? Will the identifiers be connected to the data or kept separate for contact purposes only?

This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: VO2 Max Testing

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

V02 Max testing is completed in routine monitoring to capture the athlete's aerobic capacity. This testing is completed through an instrument called WattBike which has protocols to estimate VO2 max without an advanced laboratory assessment.   This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

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This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: Weight Room Workload

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

Weight room workload is captured through an online application. Coaches input the workouts and athletes electronically check off exercises as they are completed in real-time. This allows practitioners to know how much workload was completed during a given workout. Variables are:

Tonnage
Volume
Exercise selection

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

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This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Data Source Name: Wellness Scales

When will the data be collected? Data are already collected.

Who will collect the data? Primary data source

Describe this Data Source.

These data are wellness scores collected through a software platform called Smartabase. The scales are taken from Kellman and Kolling's Recovery and Stress in Sport. These scales have been used in several research studies looking at athlete monitoring (Collette, 2018; Wiewelhove, 2018; Pelka, 2018) There are 6 items all on 0-6 point scale. An example is uploaded in the 'Instruments' section of this protocol. The items are:

Physical Performance Capability: Athletes with a high value feel strong, physically capable, energetic and full of power. In training monitoring, this item is sensitively describes recovery adaptions when using regeneration strategies.

Mental Performance Capability: A high value on this item suggests that athletes can concentrate well, are attentive and receptive, and feel alert.

Emotional Balance: Athletes with a high value indicate being in a good mood, feeling pleased and stable, and having everything under control.

Overall Recovery: Athletes with high values feel physically and mentally recovered and rested. In addition, they are muscularly and physically relaxed.

Muscular Stress: A high value suggests that athletes feel their muscles to be exhausted, fatigued, sore and stiff.

Lack of Activation: Athletes with a high value feel unmotivated and sluggish, are unenthusiastic, and lack energy in general.

Negative Emotional State: A high value points towards athletes feeling emotionally stressed by their current demand. They feel down, stressed, annoyed and short-tempered.

Overall Stress: Athletes with a high value feel tired and overloaded, and perceive themselves as physically exhausted and worn-out.

Athletes are familiarized with these items at the beginning of the season. Staff associated with the basketball teams review this data upon completion by the athlete. The survey instrument flags concerning scores in addition to the staff reviews. Concerning entries are directly discussed with the athlete and appropriate medical staff under their team procedures.

Additional items asked that are not associated with Kellman and Kolling's survey is overall body soreness, which is collected on a 10 point scale, and specific body areas which are sore (i.e., thigh, shoulder, back).

This data is already being collected as part of the team's routine athlete monitoring.

Will a recording device (e.g. audio, video, photographic) be used to collect data/materials from participants? No

Are the participant's identifying information included as part of the data at any time? Yes, and participant identifiers will be retained

What identifiers will be connected to the data and will you have access to those identifiers?

Athlete name with included with data. This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data.

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This is necessary to link longitudinal data together. Only researchers on the protocol will have access to data with names associated to data. Data will be de-identified during the data analysis process.

Associate Data Sources with Data Sources

If you are you linking the participants in a data set with their content in a different data set, use this section to associate and describe the linked Data Sources.

Data Source Name: **Anthropometrics**
✔ Data Source Name: **Athlete Availability Status**
✔ Data Source Name: **CCAPS-34**
✔ Data Source Name: **Exposure Type**
✔ Data Source Name: **Force Plates**
✔ Data Source Name: **Functional Movement Assessment**
✔ Data Source Name: **Isometric Hip and Thigh Strength**
✔ Data Source Name: **On-Court Workload**
✔ Data Source Name: **Rating of Perceived Exertion (RPE)**
✔ Data Source Name: **Sleep Tracking**
✔ Data Source Name: **Sprint Analysis**
✔ Data Source Name: **Velocity Based Training Quantification**
✔ Data Source Name: **VO2 Max Testing**
✔ Data Source Name: **Weight Room Workload**
✔ Data Source Name: **Wellness Scales**

Data Source Name: **Athlete Availability Status**
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✔ Data Source Name: **Force Plates**
✔ Data Source Name: **Functional Movement Assessment**
✔ Data Source Name: **Isometric Hip and Thigh Strength**
✔ Data Source Name: **On-Court Workload**
✔ Data Source Name: **Rating of Perceived Exertion (RPE)**
✔ Data Source Name: **Sleep Tracking**

✔ Data Source Name: **Sprint Analysis**
✔ Data Source Name: **Velocity Based Training Quantification**
✔ Data Source Name: **VO2 Max Testing**
✔ Data Source Name: **Weight Room Workload**
✔ Data Source Name: **Wellness Scales**

Data Source Name: **CCAPS-34**
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Data Source Name: **Exposure Type**
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Data Source Name: **Force Plates**
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Data Source Name: **Functional Movement Assessment**
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✔ Data Source Name: **Sprint Analysis**
✔ Data Source Name: **Velocity Based Training Quantification**
✔ Data Source Name: **VO2 Max Testing**

✔ Data Source Name: **Weight Room Workload**
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Data Source Name: **Isometric Hip and Thigh Strength**
✔ Data Source Name: **Anthropometrics**
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✔ Data Source Name: **CCAPS-34**
✔ Data Source Name: **Exposure Type**
✔ Data Source Name: **Force Plates**
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Describe the processes for linking the data:

For specific research questions, data will be pulled from applicable instruments, linked together using athlete name, and then de-identified for analysis. The linking of data across sources will be completed by a member of the research team.

Associate Data Sources with Participant Groups

No requirements.

Data Sources Upload

Instrument
View File: CCAPS 2021 Manual_Accessible.pdf
date uploaded: 2022-11-30, by: Kramer, Natalie *(nak5dy)*
This file is approved.
date approved: 2023-01-30

Instrument
View File: CCAPS_34.pdf
date uploaded: 2022-11-30, by: Kramer, Natalie *(nak5dy)*
This file is approved.
date approved: 2023-01-30

Instrument
View File: CCAPS-34__Response_Flowchart.pdf
date uploaded: 2023-01-12, by: Kramer, Natalie *(nak5dy)*
This file is approved.
date approved: 2023-01-30

Instrument
View File: kellman_kolling.pdf
date uploaded: 2021-11-17, by: Kramer, Natalie *(nak5dy)*
This file is approved.
date approved: 2021-12-22

Permission to Access Data Source and Participant Group

Are there any rules or restrictions to access Data Sources and/or Participant Groups? Yes

Describe the rules or restrictions and how you will navigate that process:

University of Virginia Athletics Department will give written permission for this study after reviewing an approved IRB protocol. This type of data collection has occurred before within the athletics department. The letter of permission to access the data will be uploaded to iProtocol once received. Data collection will not begin until evidence of this permission is submitted to the IRB.

Permissions and/or Agreements

Proof of Permission
View File: MBB research #4812.pdf

date uploaded: 2022-12-08, by: Kramer, Natalie *(nak5dy)*
This file is approved.
date approved: 2023-01-30

Data Reports & Storage

How will data/materials be stored? What measures will be taken to secure these data during collection and analysis? If the data includes recordings, what will be done with the recordings (including if/when the recordings will be destroyed)? Describe the long-term plan for maintaining the data when the active research phase is completed. Please note that you may need additional "material release" consent forms if you are using recordings for purposes beyond the study.

During data collection, data will be stored on the platforms in which they are collected for routine monitoring. These devices and platforms have been approved by UVA Athletics. For research, data will be pulled from the platforms, combined, and then de-identified. After the research question is answered, the de-identified files will be stored on a USB drive in the Department of Kinesiology. For up to 5 years after a student-athlete's career at UVA, their data may be used for analysis at UVA and in collaboration with other institutions. CCAPS-34 data will not be shared outside the research team on this protocol. For all other data, only de-identified data will be shared and only in aggregate with other data (no single persons file). Research data will be destroyed in line with University policy at the completion of active data collection.

How will data/materials be reported for this study? Will the results be reported in aggregate or will individual data be discussed?

Reports will mostly be in the aggregate. There may be certain research questions that require a case study using 1-2 athletes. In all cases, data will be de-identified and researchers will protect the identity of the athlete to the best of their ability.

If a participant decides to withdraw from the study, how will you handle their data?

For data that was already pulled and de-identified, there will be no way to withdraw their data. The participant's data will be withdrawn from future research studies.

Do you plan to publish your raw data after the study is completed *(i.e. open-access or open source publishing)*? No

Will other parties (i.e. other corporations, institutions, researchers) have access to or retain a copy of the data? Yes

International Research

Risks & Benefits

You have indicated that this study will include the **1 item** displayed in the list below. This **1 item** is an area that often requires more scrutiny from the Board. When framing your responses regarding the risks in this study, address the study as a whole, and also consider the **1 item** specifically as well.

Item:
1. includes students

Is loss of confidentiality and/or privacy a risk to participants? Yes

What will be done to protect participants from loss of confidentiality and/or privacy?

There is a small risk of loss of confidentiality and/or privacy. Once data is aggregated for research purposes, the dataset will be de-identified for analysis. Data that is not de-identified will remain in the platforms in which it was collected. These platforms have been approved by UVA Athletics for routine monitoring.

This research included student-athletes, however, academic records are not part of the study protocol.

Describe any remaining potential risks to participants. For example, are any of your participants or participant groups "risk-sensitive"? Include information about the probability of harm (i.e. how likely it is that harm will occur). What will be done to reduce risk to participants? If something unexpected involving risk happens, how will you handle it?

There is a risk that answers to specific questions on the psychological survey may warrant further evaluation by a clinical psychologist. Responses to the CCAPS-34 will not effect participant's standing as a student-athlete.

Are there direct benefits to the participants in this study? No

Describe the overall benefit of this study.

Benefits of the study may include better knowledge of how to use athlete monitoring data to enhance athlete welfare outcomes and sports performance.

Continuation

Are you applying for a continuation of your protocol's approval? No

Modification

Does this protocol version include any changes that were made to the previously approved protocol (protocol form, consent documents, etc)? *Minor edits are considered changes!* Yes

Has the level of risk changed (either increased or decreased) since the last submission? No

Provide the rationale for changing the protocol described in this study. Note that the program is able to detect changes made in the text boxes so it is not necessary to report every edit.

Additional mental health survey instrument was added. The research team decided a more in-depth mental health survey was needed to assess the effect of stressors on student-athlete well-being and health.

Unexpected Adverse Events

Did a negative event associated with the research occur and does it meet one of the following conditions:

is not described as a possibility in the previously approved protocol OR;

did not occur within the parameter described (i.e. an increase in frequency or severity)?

No

University of Virginia
Athletics Administration
P.O. Box 400846
Charlottesville, Virginia 22904-4846

December 7, 2022

To Whom It May Concern:

Dr. Hertel and his research team are approved to conduct the modified research study (Protocol #4812) by the department of athletics upon final approval by the IRB.

Sincerely,

Edward Scott, Ph.D.
Deputy Athletics Director
E.Scott@Virginia.edu

Office (434) 982-5100 - Fax (434) 982-5012

Office of the Vice President for Research

Human Research Protection Program

Institutional Review Board for the Social and Behavioral Sciences

IRB-SBS Chair: Moon, Tonya

IRB-SBS Director: Blackwood, Bronwyn

Protocol Number (4812) Approval Certificate

The UVA IRB-SBS reviewed "Athlete Monitoring in Collegiate Basketball" and determined that the protocol met the qualifications for approval as described in 45 CFR 46.

Principal Investigator: Hertel, Jay

Protocol Number: 4812

Protocol Title: Athlete Monitoring in Collegiate Basketball

Is this research funded? No

Review category: Full Board Review

Review Type:

Modifications: Yes
Continuation: No
Unexpected Adverse Events: No

Approval Date: 2023-01-30

Continuation Date: 2024-01-30

As indicated in the Principal Investigator, Faculty Sponsor, and Department Chair Assurances as part of the IRB requirements for approval, the PI has ultimate responsibility for the conduct of the study, the ethical performance of the project, the protection of the rights and welfare of human subjects, and strict adherence to any stipulations imposed by the IRB-SBS.

The PI and research team will comply with all UVA policies and procedures, as well as with all applicable Federal, State, and local laws regarding the protection of human subjects in research, including, but not limited to, the following:

1. That no participants will be recruited or data accessed under the protocol until the Investigator has received this approval certificate.
2. That no participants will be recruited or entered under the protocol until all researchers for the project including the Faculty Sponsor have completed their human investigation research ethics educational requirement (CITI training is required every 3 years for UVA researchers). The PI ensures that all personnel performing the project are qualified, appropriately trained, and will adhere to the provisions of the approved protocol.
3. That any modifications of the protocol or consent form will not be implemented without prior written approval from the IRB-SBS Chair or designee except when necessary to eliminate immediate hazards to the participants.
4. That any deviation from the protocol and/or consent form that is serious, unexpected and related to the study or a death occurring during the study will be reported promptly to the SBS Review Board in writing.
5. That all protocol forms for continuations of this protocol will be completed and returned within the time limit stated on the renewal notification letter.
6. That all participants will be recruited and consented as stated in the protocol approved or exempted by the IRB-SBS board. If written consent is required, all participants will be consented by signing a copy of the consent form unless this requirement is waived by the board.
7. That the IRB-SBS office will be notified within 30 days of a change in the Principal Investigator for the study.
8. That the IRB-SBS office will be notified when the active study is complete.
9. The SBS Review Board reserves the right to suspend and/or terminate this study at any time if, in its opinion, (1) the risks of further research are prohibitive, or (2) the above agreement is breached.

Date this Protocol Approval Certificate was generated: 2023-10-04

I. Neuromuscular Performance Measures

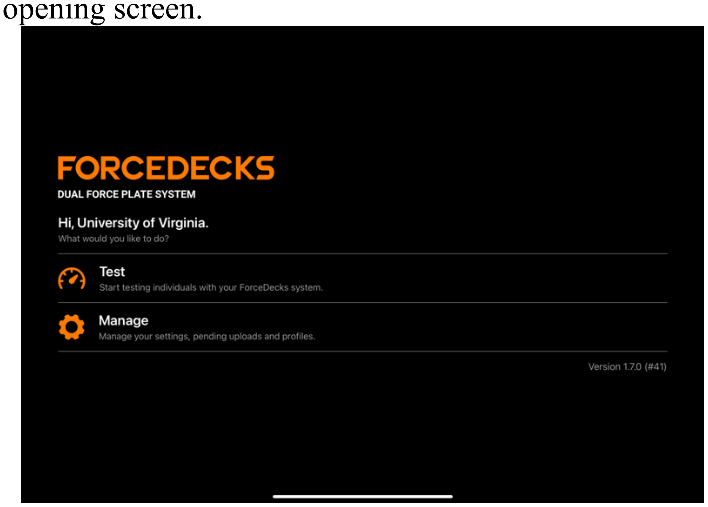
Countermovement Jump Test

Equipment

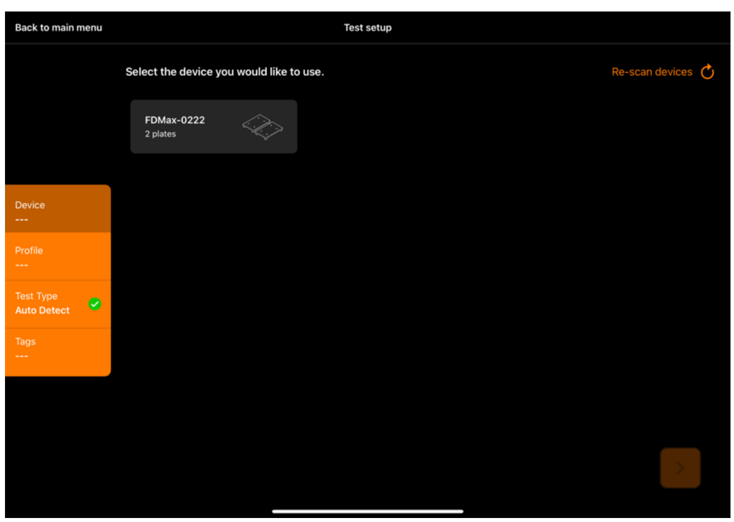
- ForceDecks FD4000 Dual Force Platform
- iPad (8^{th} Generation)
- ForceDecks IOS Application

Procedures

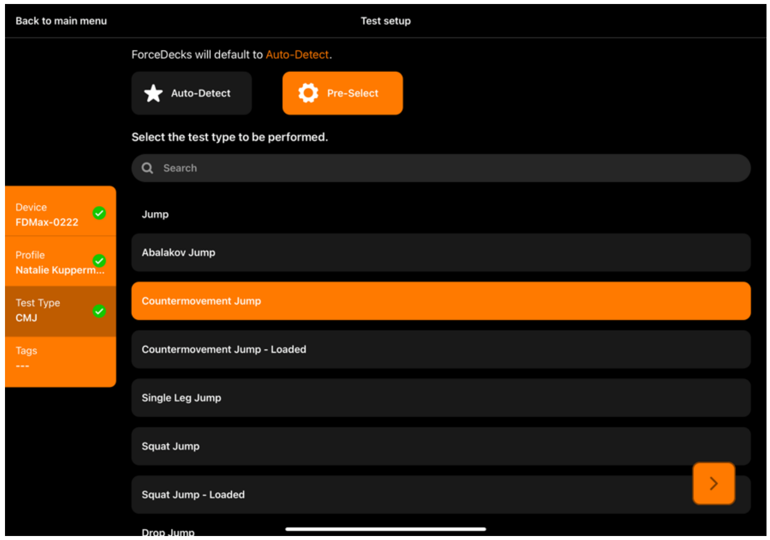
1. On the iPad (8^{th} Generation), Login "ForceDecks" application.
2. Select "Test" from opening screen.



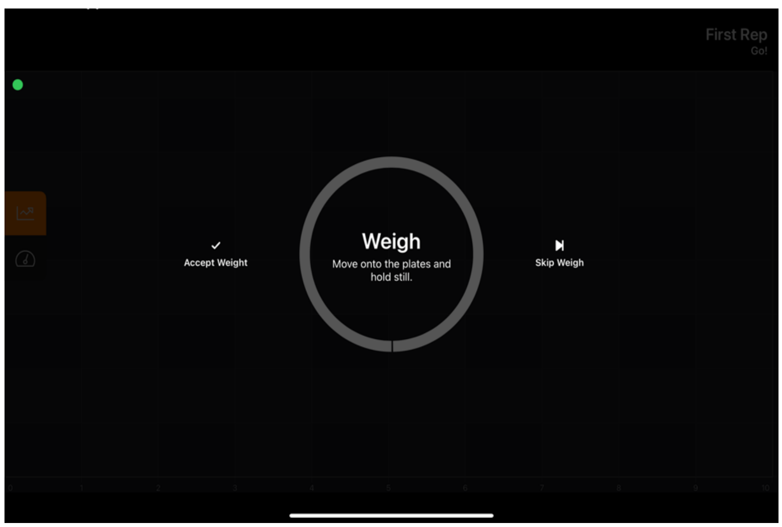
3. Establish Bluetooth connection to selected FD4000.



4. Pre-select test type "Countermovement Jump".
5. Click arrow on the bottom right.



6. Initiate test with clicking start on the bottom right, wait for the plates to calibrate to zero.
7. Instruct the athlete to step on when the application displays "Weigh" and find a quiet stance.



8. Once athlete weight is accepted, instruct the athlete to set their feet to the jumping position and find quiet stance again.
9. Once quiet stance is achieved instruct the athlete perform a maximal jump "hard and fast" with hands remaining akimbo.
10. Between jump trials the athlete is instructed find a quiet stance for 5-10 seconds before the next trial.
11. Click "Finish" once the athlete has completed 3 acceptable jumps trials.
12. Then click "upload" to send the CMJ data to the cloud.

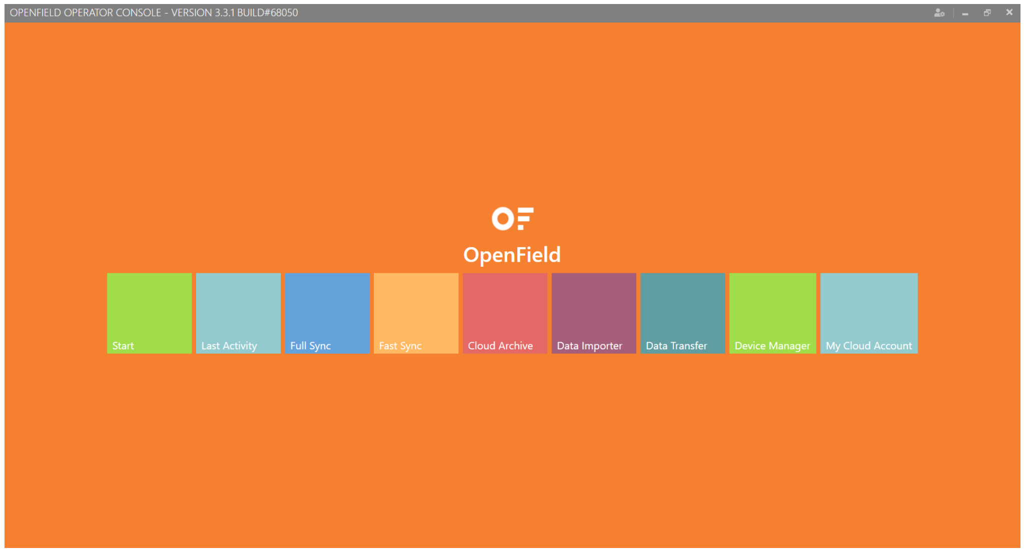
II. External Training Load Measures

Equipment

- Catapult Vector S7 & T7 IMU
  - Triaxial accelerometer, Gyroscope, Magnetometer
- Dell Laptop PC – Openfield Operator Console
- Catapult Receiver
  - Internal wireless network to collect live athlete data via telemetry.
- Openfield Operator Console Application
- Catapult Garment
  - Houses IMU unit between scapulae.
- Charging Dock
  - Charges IMU units and serve to transfer inertial data from IMU to Openfield Operator Console.

Practice Exposure Data Collection

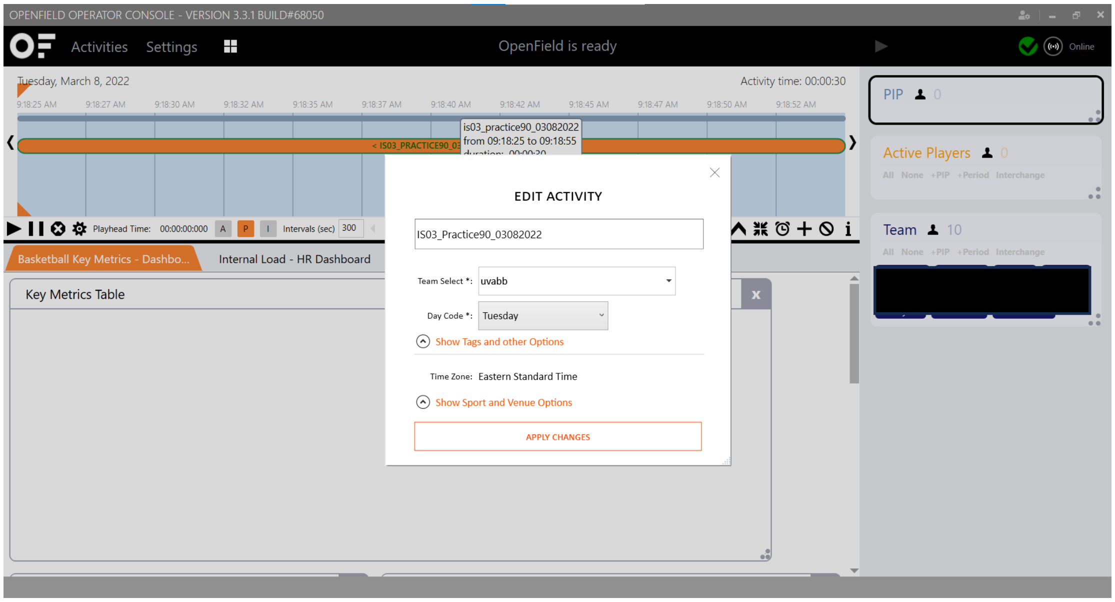
1. Assigned garments placed at each athlete's locker approximately 2 hours prior to start of practice exposure.
2. Vector S7 and T7 alarms set for initiation 45 minutes before start of practice.
   - Make sure all Vector units are plugged into console.
   - Turn on the ignition switch of the charging console.
   - Plug charging console into Catapult laptop.
   - Log in to Catapult laptop and launch Openfield,
   - Select Device Manager Tile.



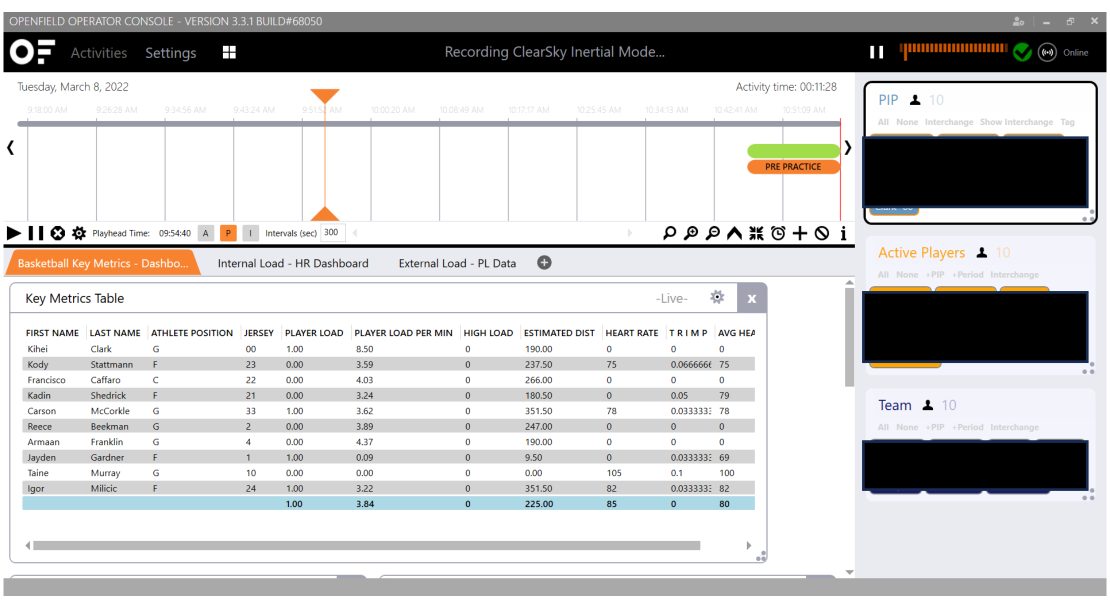
- Select Commands under Configuration
- Select all devices and make sure the appropriate number of units are populated.
- Select Execute on Set Alarm in bottom of cue.
- Enter time for alarms in military time for 45 minutes prior to practice start.
- Ensure time and date are accurate and that all devices are populated.

3. New Activity
   - Select Start Tile
   - Right click within the time field and select new activity.
   - Name activity according to season phase, activity type and number, and date.
   - e.g., Preseason_Practice01_MMDDYYYY

- Team select: UVabb
- Device Type: Inertial (No Position Data)
- Day Code: Day of week or proximity to game
- Select Show Tag and Other Options
- Participation: Full
- Activity tags:
- Year (e.g., 22-23)
- Time of year (e.g., Preseason)
- Activity type (e.g., Practice01)



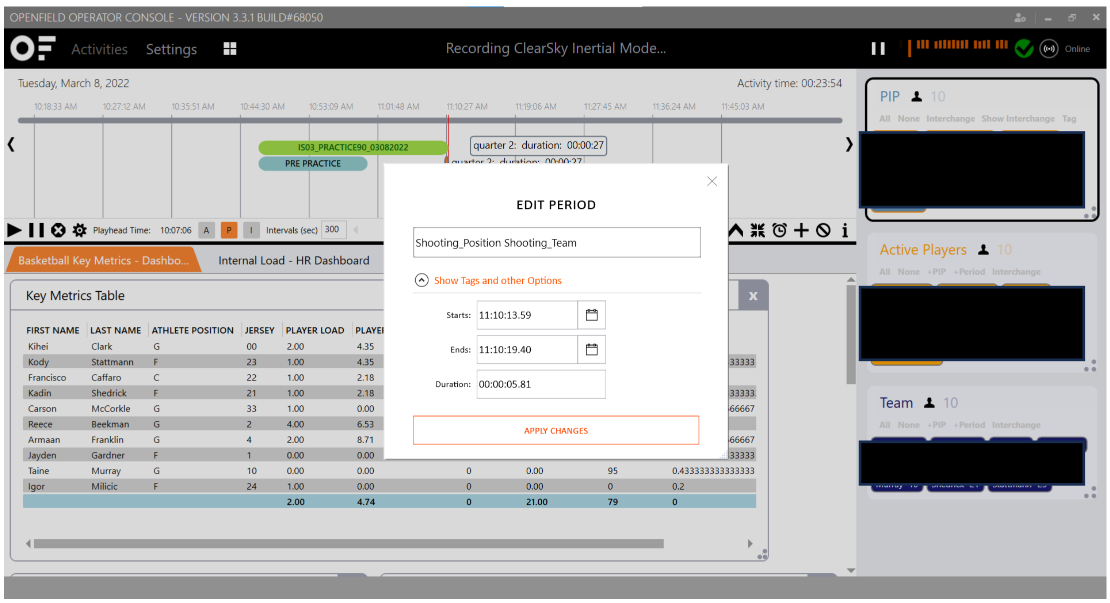
4. Initial Period
   - From Active Players or Team select all players participating and select +Period.
   - Go to PIP and select "All" then select Interchange to sub all players out of the period.
   - Assist players with IMU placement prior to engaging in practice activity.
   - Numbers on the Catapult unit should be facing out and indicator light should be illuminated. Players should be interchanged once IMUs are placed and athletes take the court.
   - Select the player's name in PIP and select Interchange to insert player into period.
   - Active players will be highlighted in orange.



5. Period Editing
   - Right click the period you wish to edit and select "Edit".

- The first period will usually be labeled “Pre Practice”.

  - Periods will be named according to the type of segment, emphasis of the segment, title of the segment, identified as full court or half court, the size of the segment, and each portion of the name separated by underscores
  - Segment type: Drill, play, instructional
  - Emphasis: Defense, offense
  - Name of segment: reference practice sheet
  - Full court or half court *This does not apply to a lot of drills where the nature of the segment lends it to being half court
  - Size: e.g. 1v1, 3v3, 5v5, Team
  - e.g. Drill_Defense_Close Outs_2v2



6. Tagging Periods
   - Tags should match the period name.
   - Select Show Tags from drop down menu.
   - Select tags according to period name and objective of period.
   - Periods also need to be tagged “Countable” during coach led activities. “Non-Countable” when the coaches are not involved in instruction (e.g., Pre Practice).
7. Period Management
   - Periods should be started when movement associated with the period is initatied.
   - Periods should be ended by right clicking and selecting “Stop” when the segment is completed.
   - All players are included in the period unless deemed otherwise.
   - Start and end time of periods can be edited by right clicking the period, selecting “Edit”, and adjusting the start and end times.
8. Termination of Practice
   - The final countable period complete when coach led activity is terminated. Any additional period should be labeled “Extra Work” and tagged as “Non-Countable”.

- Athletes should removed from the period by "Interchange" as they come off the court.
- Collection of Catapult IMUs and garments as athletes leave the playing court.
- End the last period as the last athlete leaves the playing court.

9. Collection of Data
    - Return the receiver and USB to the charging console carrying case.
    - Catapult garments are placed on a loop and turned in to the equipment room for sanitation.
        - Insure no Catapult IMUs are remain in garments.
    - Disinfect IMU and place unit in charging ports. Units should be toggled off before placement into charging port.
    - Turn on "Ignition" button on charging console and plug the charging console USB into the Openfield laptop PC.
    - Select "Data Transfer" from tiles.
    - Select Yes when prompted to close any current activities.
    - Make sure all Catapult units are populated and showing a white light on the front of the unit.
    - Each IMU unit should go through the following steps for data transfer: Queued for download→ Downloading→ Processing→ Queued for import→Import→ Finished
    - Exit screen by "X" out when all units are finished downloading.
10. Cleaning Data
    - From the tiles select "Last Activity".
    - Select All in PIP and right click on one person's name. Select Graph.
    - Drag the Metrics table down to view player data graphs.
    - Left click and drag the table to see the first period.
    - Review player graphs for each period to insure athlete was included in period accurately. The shaded green box over each player's indicates when the player is in the period.
        - Substituted in too early: there will be a period of no activity at the front of their light green box.
            - To substitute player out of the period, select that period, hold "shift+cntrl" and proceed to drag over the time period that the athlete needs to be benched.
            - The green box over this area should go away.
        - Substituted in too late: there will be periods of activity before their shaded green box.
            - To substitute this player into the period, select that period, hold "ctrl" and drag from the first indicator of activity in the graph.
        - The same process should be repeated for the final period.
        - Review each period to ensure data accuracy for each player.
        - Select "Reprocess/Bake Activity"→ Full to reprocess clean activity data.
        - From tiles and select "Full Sync" to forward data to Openfield cloud.
        - Upon completion of data sync shut down Openfield laptop PC.

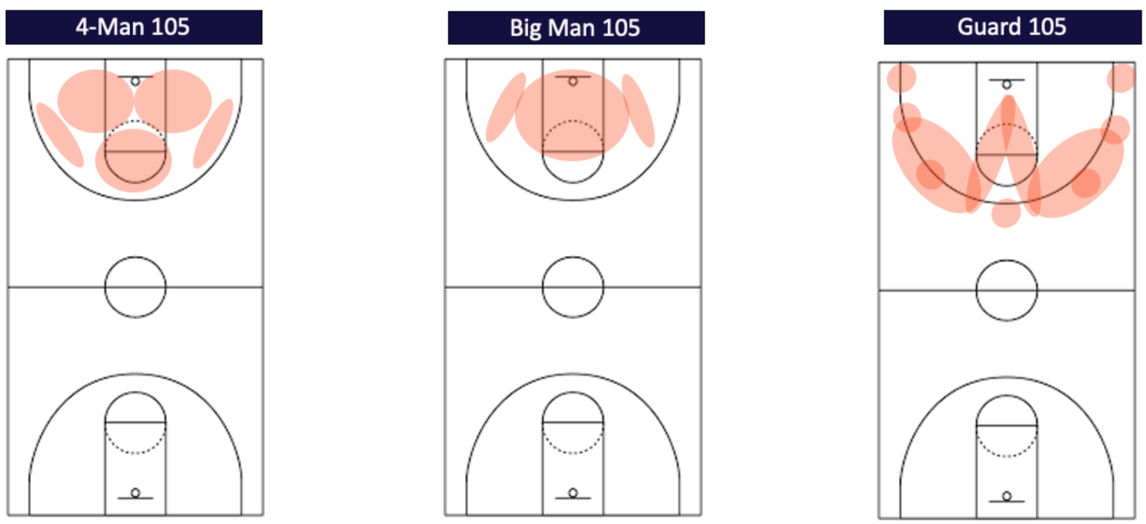
III. Shooting Accuracy Measures

Equipment

- Standard 10-foot basketball backboard and rims
- Nike Elite Basketballs

Procedures

1. Warm-Up
    - Athletes engage in standardized warm-up activities consisting of soft tissue work, skipping, locomotion, and plyometrics in the performance center prior court work.
    - Athletes place Catapult S7 or T7 IMU devices into garments for external training load measurement.
2. Shooting Task
    - Athletes engage in shooting task based on positional assignment.
    - Graduate and student assistants facilitate the battery of shoots through rebounding and passing for athlete engaged in recorded task.
    - Athlete completes a segment of shooting battery and then rest while partner athlete completes their segment.
    - Dependent on positional assignment, athlete completes shooting tasks in designated areas on the basketball court.



3. Data Collection
    - Graduate and student assistant records shot percentage (shoots made divided by shots taken) for each segment of the shooting battery.
    - At the completion of the shooting task, graduate or student assistant calculates total shooting percentage for complete battery and records data in the customized spreadsheet (Excel, Microsoft Corporation).

IV. Sleep Measures

Equipment

- Oura Ring (Generation 3)
- Iphone
- Oura IOS application

Procedures

1. Measuring Sleep

- Athlete instructed to charge Oura ring prior to engaging in sleep preparation (e.g., turning of lights and lying in the bed).
- Athlete instructed to place the Oura ring on the selected finger approximately 10-15 minutes before sleep preparation.
- Athletes were instructed to wear the Oura ring during the entire night's sleep (e.g., time in bed) and only remove the device once sleep is complete and the athlete begins engagement in their morning routine (e.g., brushing teeth, consumption of breakfast, etc.).

2. Data Collection
   - Athletes instructed to sync sleep data to IOS application on their iPhones during the morning hours before leaving their homes.
   - They were instructed to open the application and hold the ring in close proximity to the phone so data could be transferred via Bluetooth to the application.
   - Upon data synchronization to the application data was transferred to the Oura cloud. Then an API transferred data to the Smartabase athlete management system for extraction for data analysis.

V. Athlete Self-Report Measures

A. Short Recovery and Stress Scales

Equipment

- Ipad (8th generation)
- Smartabase Kiosk Application

Procedure

- The SRSS is uploaded to the Smartabase Kiosk application for delivery to athletes.

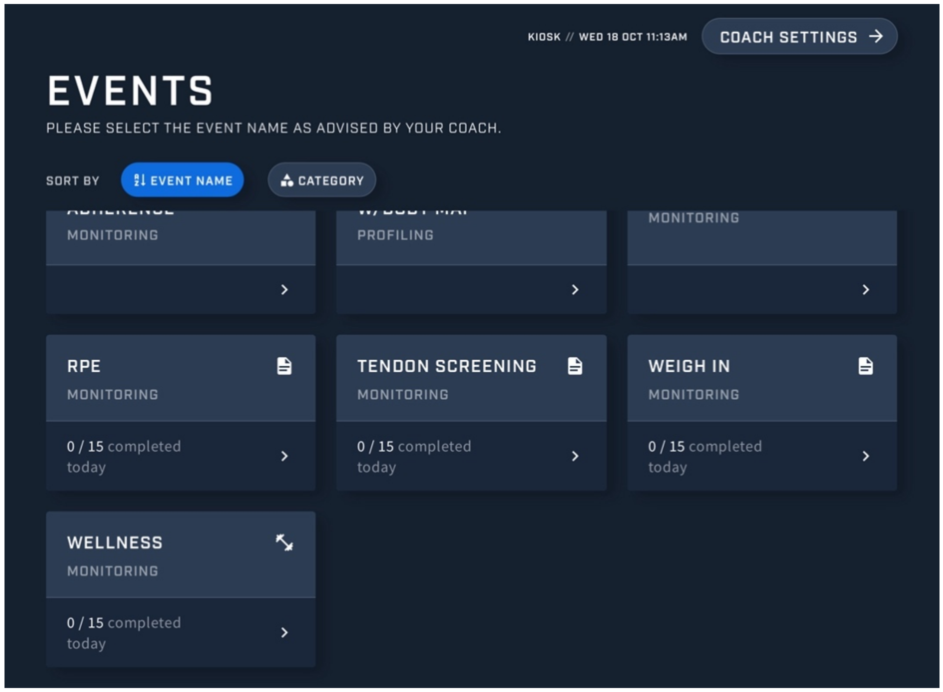
Name/Code	Date/Time

Short Recovery Scale

Below you find a list of expressions that describe different aspects of your current state of recovery. Rate how you feel **right now** in relation to your best ever recovery state.

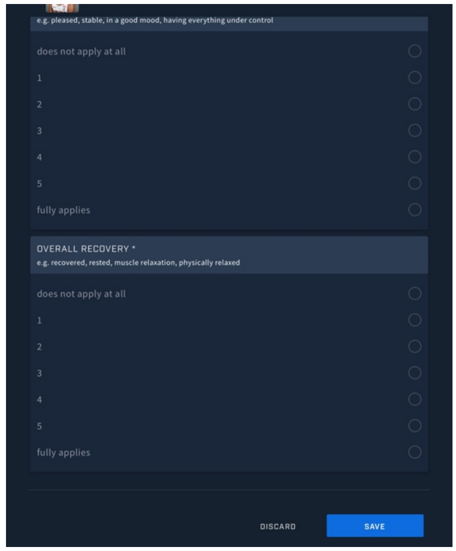
		0	1	2	3	4	5	6	
Physical Performance Capability *e.g* *strong,* *physically capable,* *energetic,* *full of power*	does not apply at all	○	○	○	○	○	○	○	fully applies
Mental Performance Capability *e.g* *attentive,* *receptive,* *mentally alert,* *concentrated*	does not apply at all	○	○	○	○	○	○	○	fully applies
Emotional Balance *e.g* *pleased,* *stable,* *in a good mood,* *having everything under control*	does not apply at all	○	○	○	○	○	○	○	fully applies
Overall Recovery *e.g* *recovered,* *rested,* *muscle relaxation,* *physically relaxed*	does not apply at all	○	○	○	○	○	○	○	fully applies

- Open Smartabase application on Ipad.
- Select "Wellness" from the Events page.



- From Wellness page click on athlete whose data will be entered.
- Instruct the athlete to complete the survey instrument in insolation without conversation or interactions with teammates.
- The athlete is instructed to complete questions related to perceived sleep duration and areas of body soreness before completing the SRSS.

- Upon completion of the items the athlete should click the save button on the lower right-hand corner for data to be transferred to the Smartabase cloud for extraction and analysis.



B. CCAPS-34

Equipment

- Ipad (8th generation)
- Smartabase Kiosk Application

Procedures

- The CCAPS-34 is uploaded to the Smartabase Kiosk application for delivery to athletes.

Counseling Center Assessment of Psychological Symptoms — **CCAPS-34**

Name: ______________________________ **Date:** ______________

INSTRUCTIONS: The following statements describe thoughts, feelings, and experiences that people may have. Please indicate how well each statement describes you, **during the past two weeks**, from "not at all like me" (0) to "extremely like me" (4), by marking the correct number. Read each statement carefully, select only one answer per statement, and please do not skip any questions.

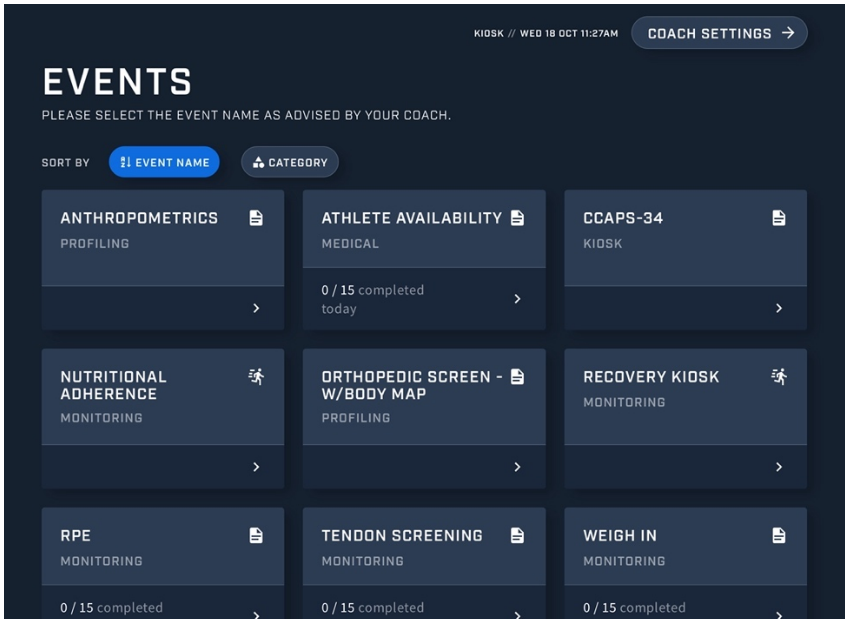
	Not at all like me				Extremely like me
1. I am shy around others	0	1	2	3	4
2. My heart races for no good reason	0	1	2	3	4
3. I feel out of control when I eat	0	1	2	3	4
4. I don't enjoy being around people as much as I used to	0	1	2	3	4
5. I feel isolated and alone	0	1	2	3	4
6. I think about food more than I would like to	0	1	2	3	4
7. I am anxious that I might have a panic attack while in public	0	1	2	3	4
8. I feel confident that I can succeed academically	0	1	2	3	4
9. I have sleep difficulties	0	1	2	3	4
10. My thoughts are racing	0	1	2	3	4
11. I feel worthless	0	1	2	3	4
12. I feel helpless	0	1	2	3	4
13. I eat too much	0	1	2	3	4
14. I drink alcohol frequently	0	1	2	3	4
15. I have spells of terror or panic	0	1	2	3	4
16. When I drink alcohol I can't remember what happened	0	1	2	3	4
17. I feel tense	0	1	2	3	4
18. I have difficulty controlling my temper	0	1	2	3	4
19. I make friends easily	0	1	2	3	4
20. I sometimes feel like breaking or smashing things	0	1	2	3	4
21. I feel sad all the time	0	1	2	3	4
22. I am concerned that other people do not like me	0	1	2	3	4
23. I get angry easily	0	1	2	3	4
24. I feel uncomfortable around people I don't know	0	1	2	3	4
25. I have thoughts of ending my life	0	1	2	3	4
26. I feel self conscious around others	0	1	2	3	4
27. I drink more than I should	0	1	2	3	4
28. I am not able to concentrate as well as usual	0	1	2	3	4
29. I am afraid I may lose control and act violently	0	1	2	3	4
30. It's hard to stay motivated for my classes	0	1	2	3	4
31. I have done something I have regretted because of drinking	0	1	2	3	4
32. I frequently get into arguments	0	1	2	3	4
33. I am unable to keep up with my schoolwork	0	1	2	3	4
34. I have thoughts of hurting others	0	1	2	3	4

PennState

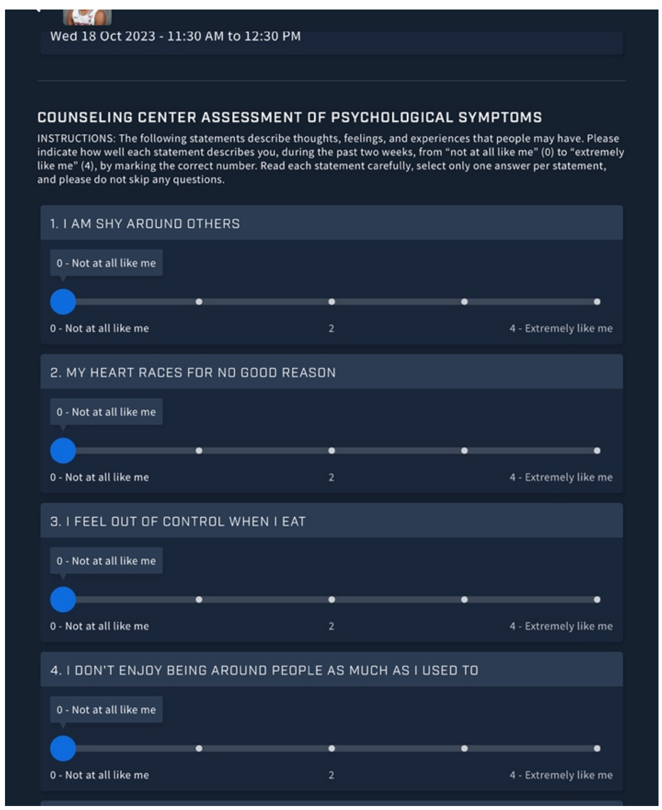
The Center for Collegiate Mental Health
http://ccmh.psu.edu
ccmh@psu.edu
814-865-1419

BRINGING SCIENCE AND PRACTICE Together.

- Open Smartabase application on Ipad.
- Select "Wellness" from the Events page.



- From CCAPS-34 page click on athlete whose data will be entered.
- Instruct the athlete to complete the survey instrument in insolation without conversation or interactions with teammates.



- Upon completion of the items the athlete should click the save button on the lower right-hand corner for data to be transferred to the Smartabase cloud for extraction and analysis.

APPENDIX D

OPERATIONAL DEFINITIONS

Operational Definitions Table D3.1 Complete List of External Training Load Variables

Variable	**Operational Definition**
Catapult Sensor: S7 & T7	
PlayerLoad	The sum of the accelerations across all axes of the internal tri-axial accelerometer during movement. It takes into account the instantaneous rate of change of acceleration and divides it by a scaling factor (divided by 100). It can also be thought of as a cumulative acceleration load variable.
3-Day Rolling PlayerLoad	Rolling average of PlayerLoad™
Accumulated PlayerLoad	Accumulated PlayerLoad™
Inertial Movement Unit	microsensor incorporating an accelerometer, a gyroscope, and a magnetometer used to measure athlete movement and activity.

Additional Results Table D3.2 Complete List of External Training Load Variables

Variable	Phase	Operational Definition
Braking phase duration (s)	Braking	Duration of the eccentric breaking phase (time from minimum vertical force to the start of the concentric phase)
Braking phase duration:concentric duration	Braking/Propulsion	Ratio of braking duration and concentric phase duration
Braking phase duration:contraction time	Braking/Propulsion	Ratio of braking phase duration and contraction time
Concentric mean force (N)	Propulsion	Mean vertical force during the concentric phase
Concentric duration (ms)	Propulsion	Duration of concentric phase (time from zero velocity to take-off)
Concentric impulse - 100ms (Ns)	Propulsion	Absolute impulse of vertical force during the first 100 ms of the concentric Phase
Concentric impulse - 100ms:concentric impulse	Propulsion	Absolute impulse of vertical force during the first 100 ms of the concentric phase divided by the net impulse of vertical force during the concentric phase
Concentric impulse - 50ms (Ns)	Propulsion	Absolute impulse of vertical force during the first 50 ms of the concentric phase
Concentric impulse (Ns)	Propulsion	Net impulse of vertical force during the concentric phase
Concentric mean power	Propulsion	Mean power during concentric phase
Concentric peak force (N)	Propulsion	Peak vertical force during the concentric phase
Concentric peak velocity (m/s)	Propulsion	Peak velocity during concentric phase
Contraction time		Time from start of movement to take-off
Countermovement depth (cm)	Unweighting/Braking	Minimum displacement achieved prior to take-off

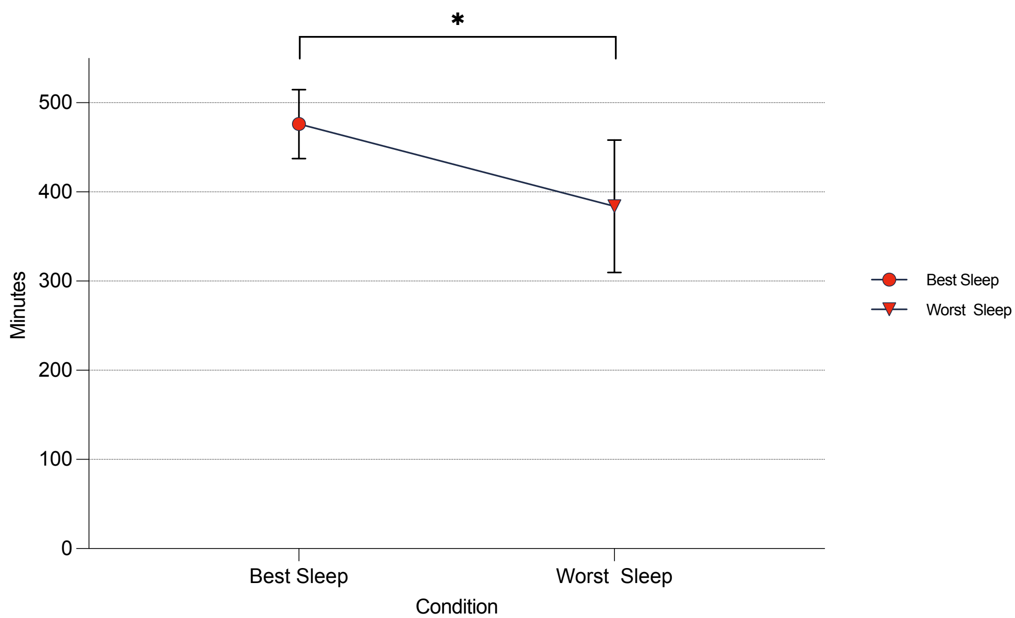
Eccentric acceleration phase duration (s)	Braking	Time from start of movement to minimum velocity (maximum negative velocity)
Eccentric braking impulse (Ns)	Braking	Absolute impulse of vertical force during the eccentric breaking phase
Eccentric deceleration phase duration (s)	Braking	Duration of eccentric deceleration phase
Eccentric deceleration RFD (N/s)	Braking	Rate of force development for vertical force during the eccentric deceleration phase
Eccentric deceleration impulse (Ns)	Braking	Absolute impulse of vertical force during the eccentric deceleration phase
Eccentric duration	Braking	Duration of the eccentric phase
Eccentric mean braking force (N)	Braking	Mean force during the eccentric braking phase
Eccentric mean deceleration force (N)	Braking	Mean force during the eccentric deceleration phase
Eccentric mean force (N)	Braking	Mean vertical force during the eccentric phase
Eccentric mean power (W)	Braking	Mean power during the eccentric phase
Eccentric peak force (N)	Braking	Peak vertical force during the eccentric phase
Eccentric peak power (W)	Braking	Peak power during the eccentric phase
Eccentric peak power:concentric peak power	Braking	Ratio of eccentric peak power to concentric peak power
Eccentric peak velocity (m/s)	Braking	Minimum velocity (peak negative velocity) force during the eccentric phase (velocity at start of eccentric breaking phase)
Eccentric unloading impulse (Ns)	Braking	Net impulse from start of movement to start of deceleration phase
Eccentric:concentric mean force ratio (%)	Braking	Ratio of eccentric mean force and concentric mean force, expressed as a percentage
Flight time (ms)	Flight	Time between take-off and landing
Force at peak power (N)		Vertical force at moment of peak power
Force at zero velocity (N)		Vertical force at moment of zero velocity prior to take-off
Jump height [flight time] relative landing RFD (N/s/cm)	Flight/Landing	Landing RFD divided by jump height (flight time)

Jump height [flight time] relative peak landing force (N/cm)	Flight/Landing	Peak landing force divided by jump height (flight time)
Jump height [flight time] (cm)	Flight	Jump height calculated from flight time
Jump height [impulse-displacement] (cm)	Flight	Maximum displacement between take-off and landing
Jump height [impulse-momentum] (cm)	Flight	Jump height calculated by taking velocity at the instant of take-off and predicting the maximum vertical displacement of the center of mass based on body mass
Landing impulse (Ns)	Landing	Absolute impulse during landing phase
Landing RFD - 50ms (Ns)	Landing	Absolute impulse of vertical force during the first 50ms of the landing phase
Landing RFD (N/s)	Landing	Rate of force development of vertical force between landing and peak landing force
Mean eccentric + concentric power:time (W/s)	Braking/Propulsion	Mean power over eccentric phase and concentric phase divided by contraction time
Mean landing acceleration (m/s/s)	Landing	Mean acceleration from landing until end of trial
Mean landing power (W)	Landing	Mean power from landing until end of trial
Mean landing velocity (m/s)	Landing	Mean velocity during landing phase
Mean take-off acceleration (m/s/)	Propulsion	Mean acceleration prior to takeoff
Mean take-off velocity (m/s)	Propulsion	Mean velocity prior to takeoff
Minimum eccentric force (N)	Braking	Minimum force during the eccentric phase
Movement start to peak force (s)		Time between peak force and take-off peak force
Movement start to peak power (s)		Time between peak force and take-off peak power
P1 concentric impulse (Ns)	Propulsion	Net impulse for vertical force during 1st 50% (time-wise) of concentric phase
P2 concentric impulse (Ns)	Propulsion	Net impulse for vertical force during 2nd 50% (time-wise) of concentric phase
P2 concentric impulse:P1 concentric impulse	Propulsion	Net impulse for vertical force during 2nd 50% of concentric phase divided by net impulse for vertical force during 1st 50% of concentric phase

Peak landing acceleration (m/s/s)	Landing	Maximum acceleration from landing until end of trial
Peak landing force [N]	Landing	Peak vertical force following landing
Peak landing power (W)	Landing	Peak power following landing
Peak landing velocity (m/s)	Landing	Minimum velocity (peak negative velocity) following landing
Peak power (W)		Maximum power during the concentric phase
Peak takeoff acceleration (m/s/s)	Propulsion	Peak acceleration prior to take-off
Positive impulse (Ns)		Positive impulse for vertical force from start of movement to end of trial
Positive take-off impulse (Ns)		Positive impulse for vertical force from start of movement to take-off
RSI-modified		Jump height (flight time) divided by contraction time
Takeoff peak force (N)	Propulsion	Maximum vertical force over from start of movement to take-off
Time to braking phase (s)	Braking	Time from start of movement to start of eccentric breaking phase
Total work (J)		Integration of power (area under power-time curve) from the start of movement until take-off
Velocity at peak power (m/s)		Velocity at peak power (from start of movement to take-off)
Vertical velocity at takeoff (m/s)	Propulsion	Velocity at takeoff
Weight	Quiet Stance	Athlete's body mass at start of trial

APPENDIX E

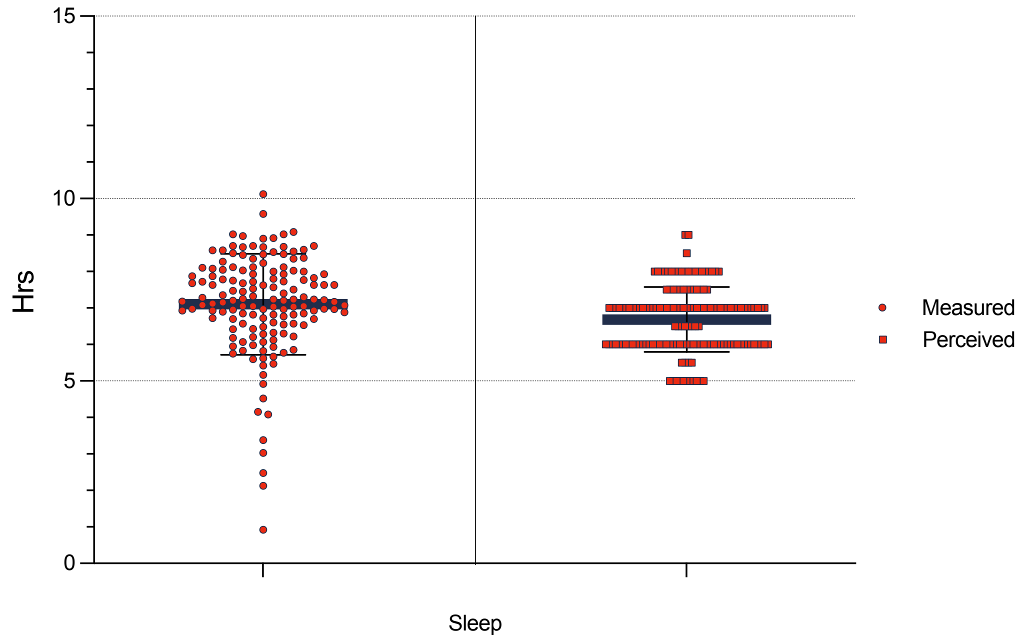
ADDITIONAL RESULTS



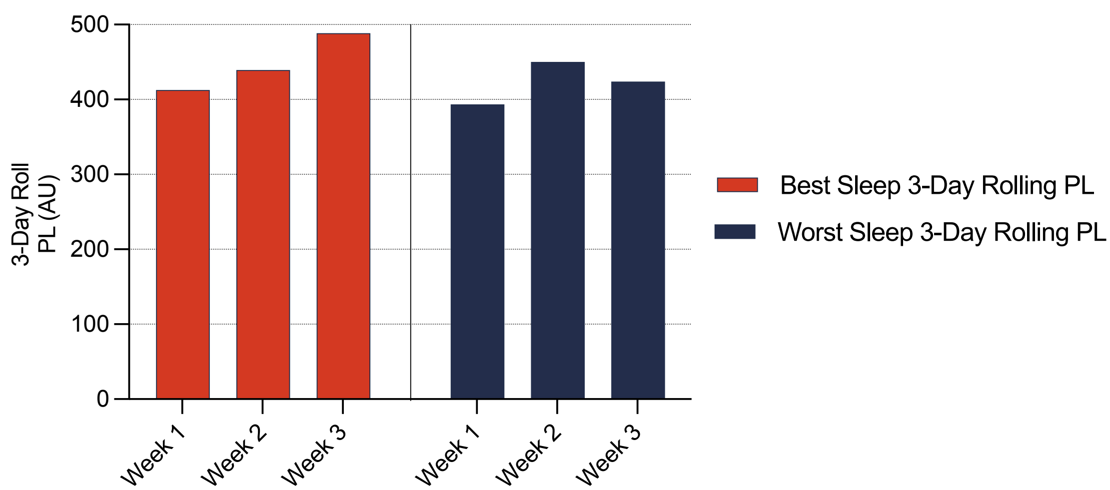
Additional Findings Figure E1.1 Best Sleep vs. Worst Sleep
Data presented as Mean (Standard Deviation). * = Significant difference between Best and Worst sleep; Statistical significance set at $p < 0.05$.

Measured vs. Perceived Sleep

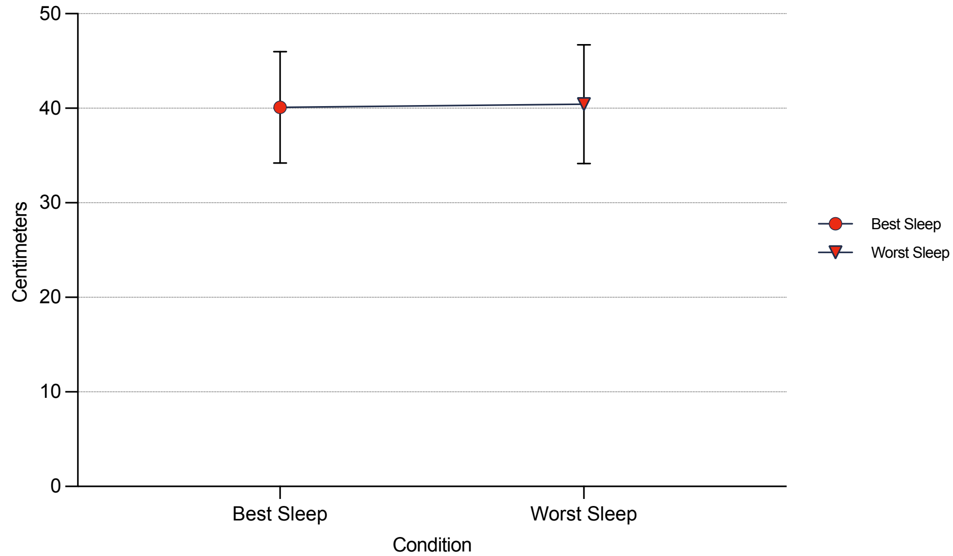
A paired samples revealed a significant difference between Measured (*M* = 7.10 ± 1.39 hours) and Perceived (*M* = 6.70 ± .89 hours). Perceived sleep duration was statistically significant and small with 0.40 hours greater than perceived sleep (t)(146) = 2.80, p = .006, 95% CI [.067, .394], Cohen's d = 0.29 95% [-0.52, -0.06] . See Figure E1.2.



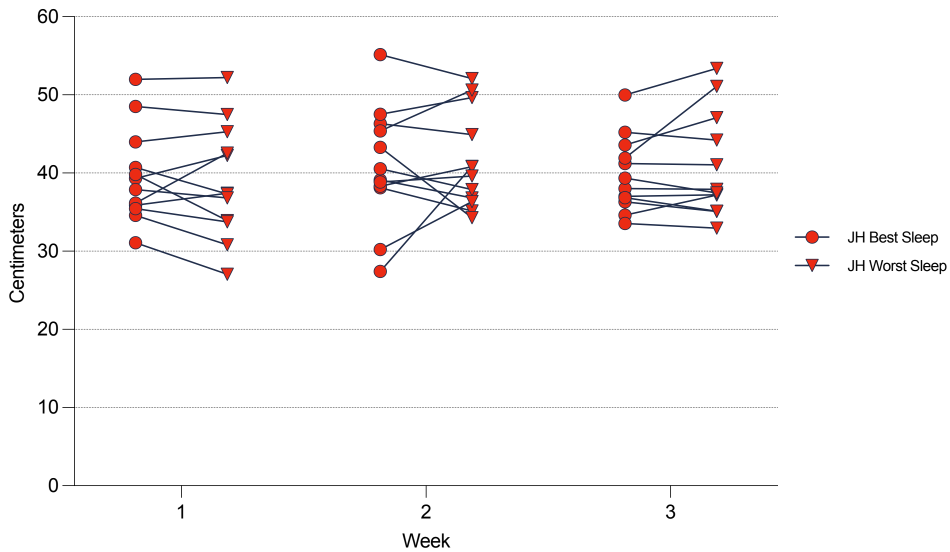
Additional Findings Figure E1.2 Measured vs. Perceived Sleep Duration



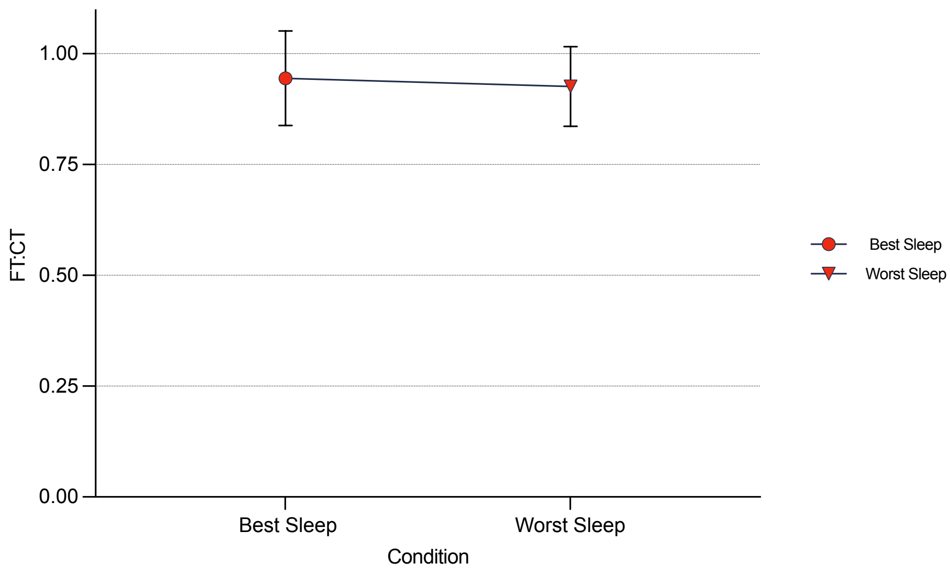
Additional Findings Figure E1.3. Best Sleep vs. Worst Sleep 3-Day Rolling Average by Week



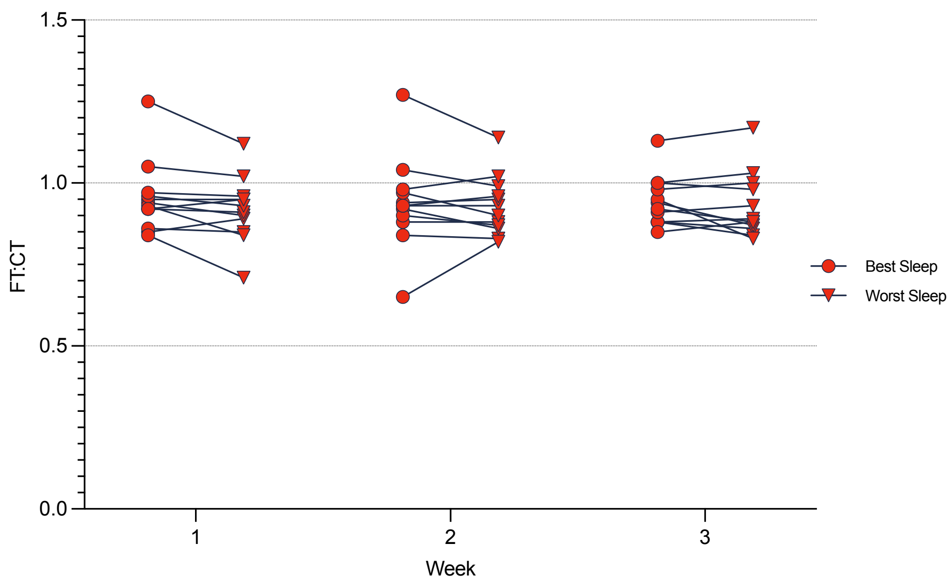
Additional Findings Figure E1.4. Mean JH by Condition
Note: Data presented as Mean (Standard Deviation).



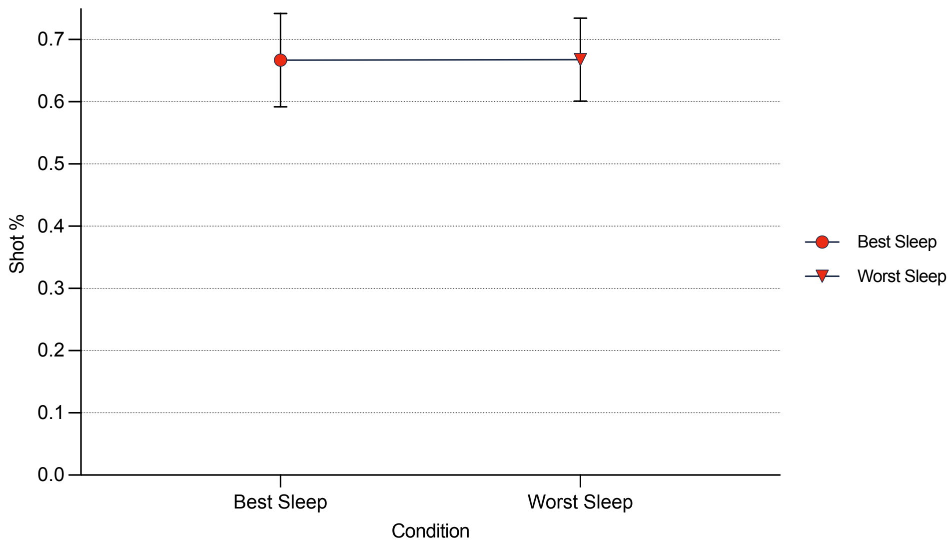
Additional Findings Figure E1.5. Individual JH by Condition Across Time



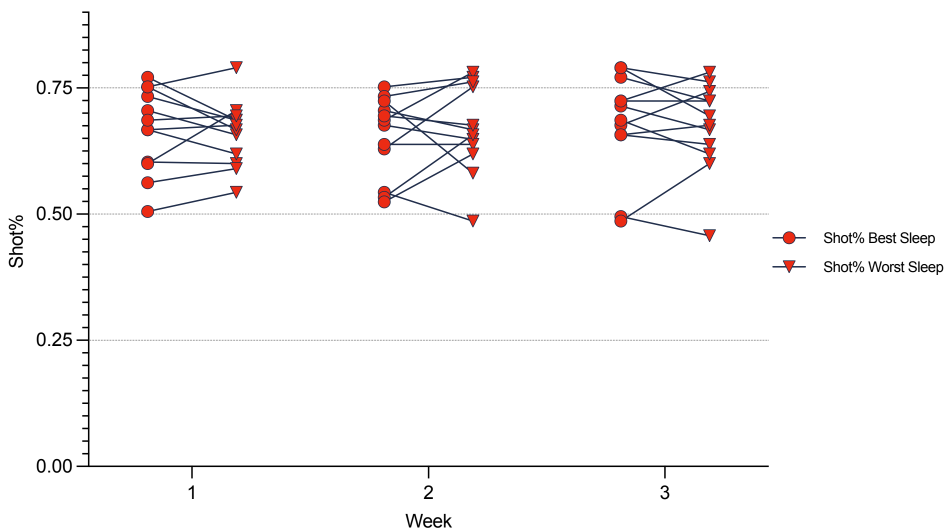
Additional Findings Figure E1.6. Mean FT:CT by Condition
Note: Data presented as Mean (Standard Deviation).



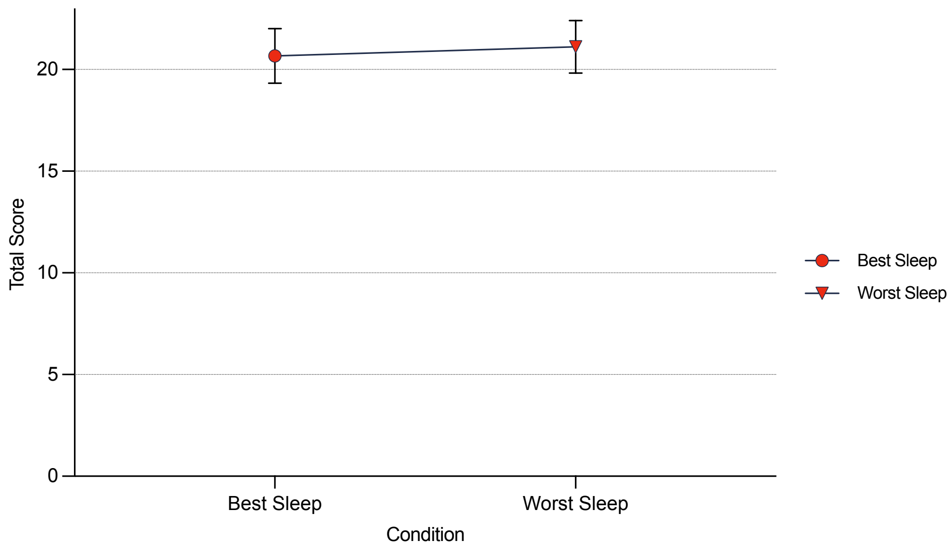
Additional Findings Figure E1.7. Individual FT:CT by Condition Across Time



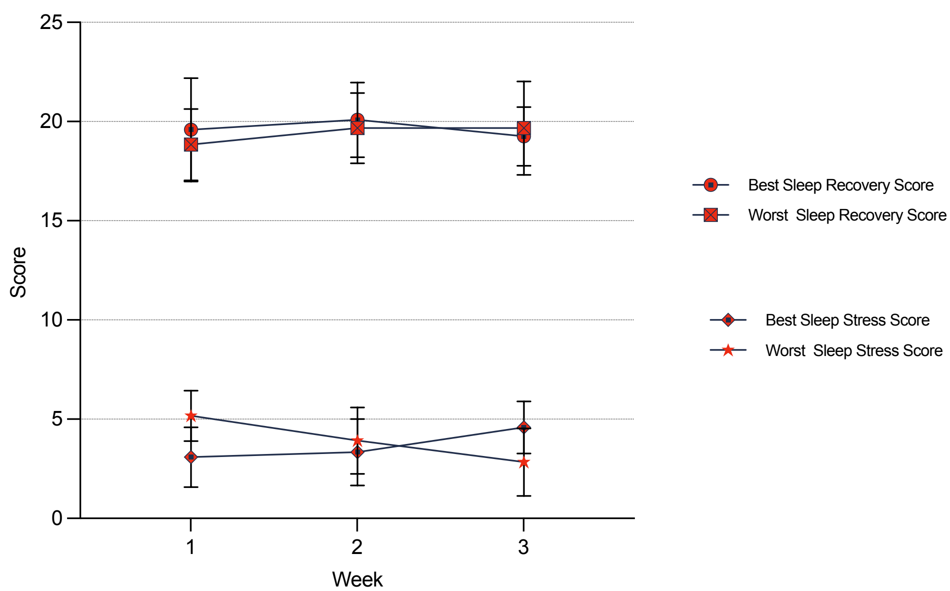
Additional Findings Figure E1.8. Mean Shot Percentage by Condition
Note: Data presented as Mean (Standard Deviation).



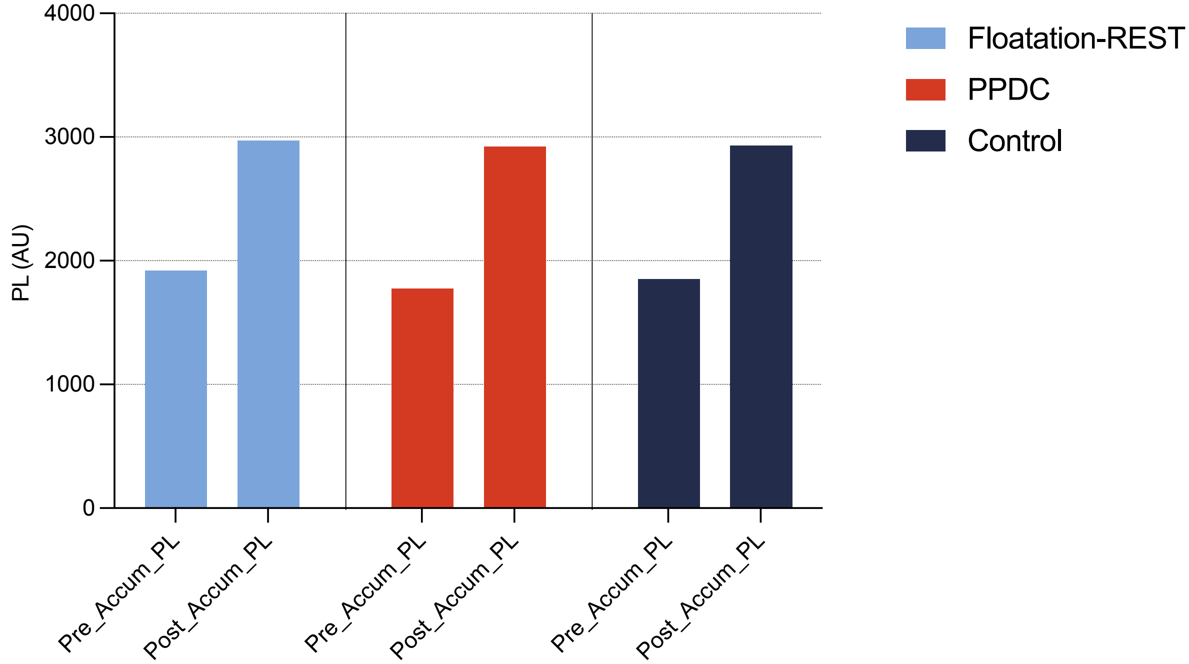
Additional Findings Figure E1.9. Individual Shot Percentage by Condition Across Time



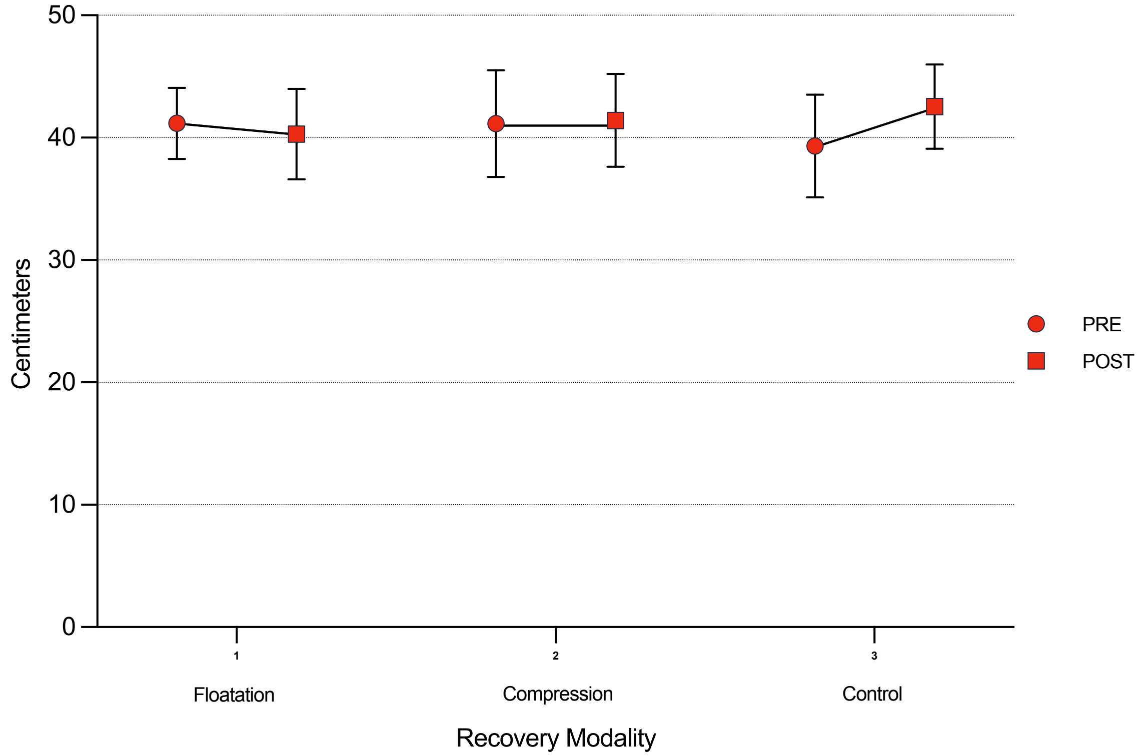
Additional Findings Figure E1.10. Mean Wellness by Condition
Note: Data presented as Mean (Standard Deviation).



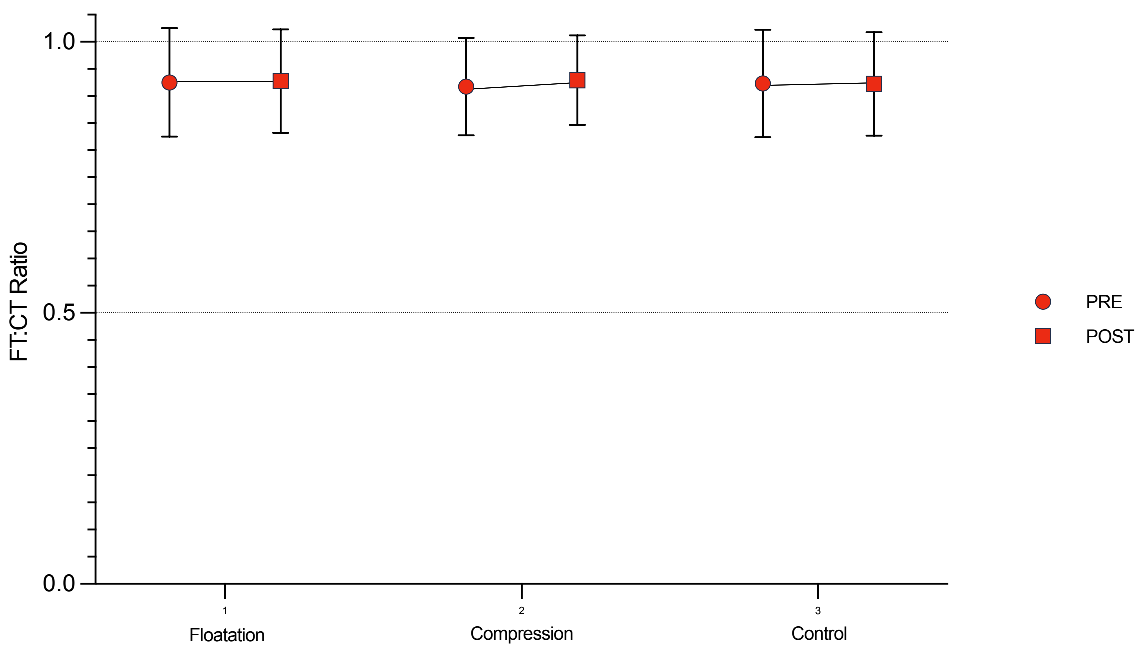
Additional Findings Figure E1.11. Mean Wellness Domain by Condition Across Time
Note: Data presented as Mean (Standard Deviation).



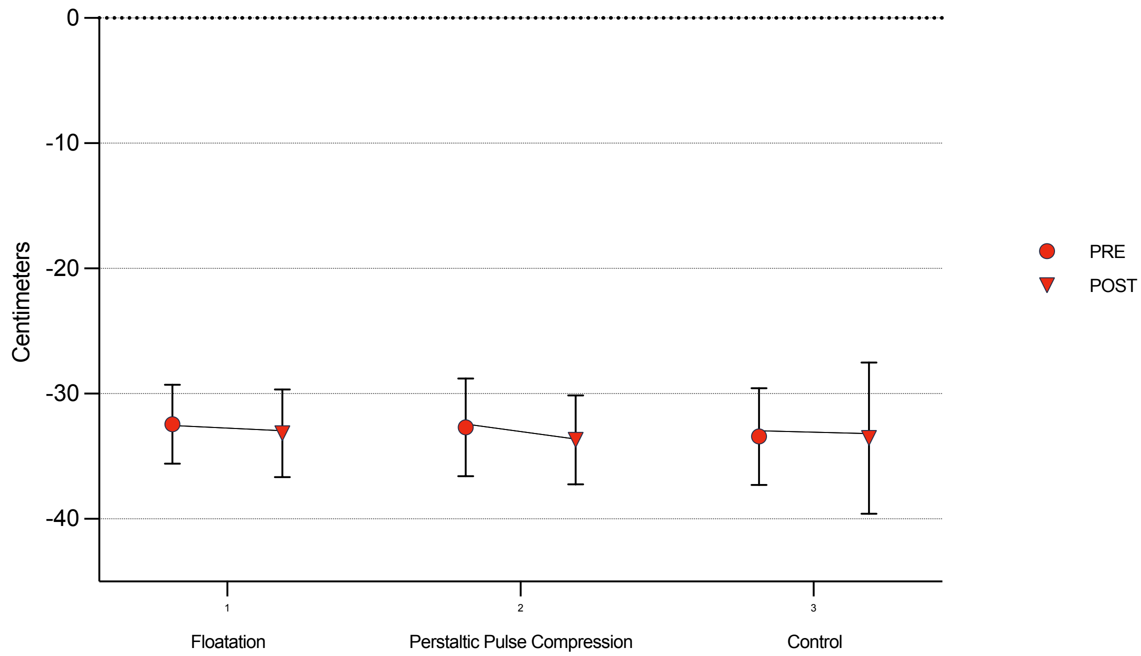
Additional Findings Figure E2.1. Pre to Post Accumulated by Across Intervention
Note: Data presented as Mean (Standard Deviation). Floatation = Floatation-REST; Compression = PPDC. Floatation-REST Accum_PL (Pre *M* = 1918.43, *SD* = 156.50; Post *M* = 2907/37, *SD* = 481.47);PPDC Accum_PL (Pre *M* = 1776.41, *SD* = 533.13; Post *M* = 2923.32, *SD* = 533.13);Control Accum_PL (Pre *M* = 1849.82, *SD* = 273.72; Post *M* = 2929.81, *SD* = 399.26).



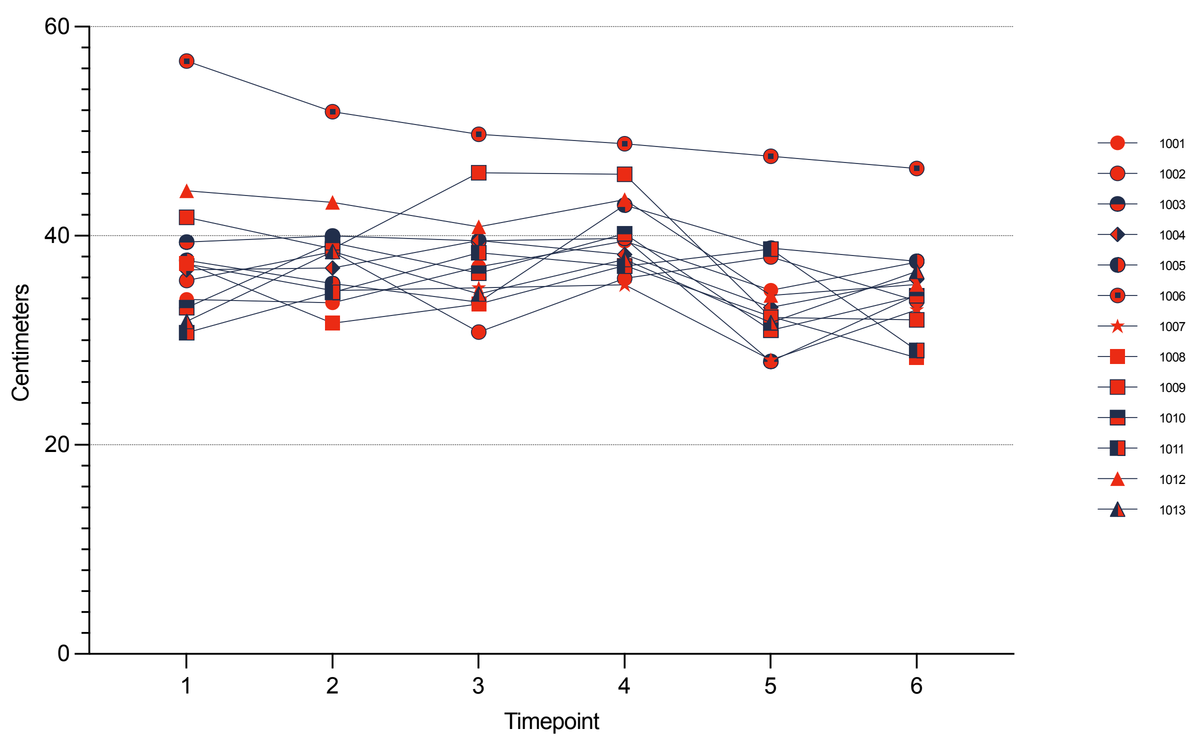
Additional Findings Figure E2.2. Mean JH by Time Across Intervention
Note: Data presented as Mean (Standard Deviation). Floatation = Floatation-REST; Compression = PPDC.



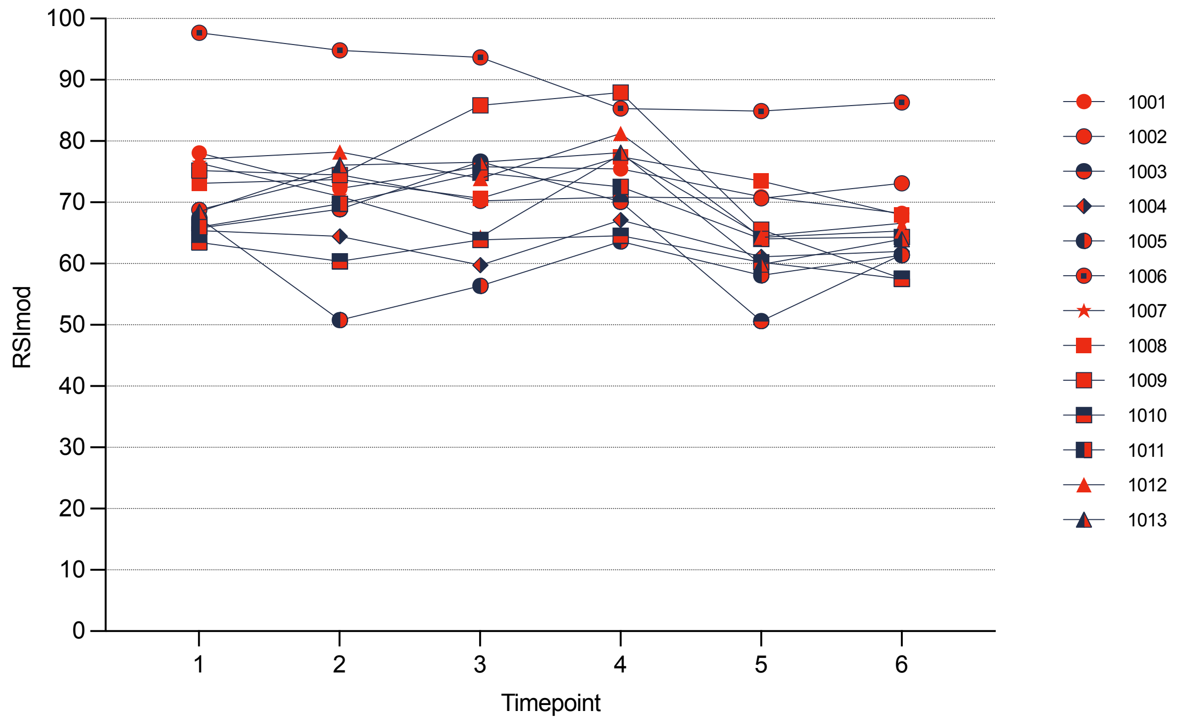
Additional Findings Figure E2.3. Mean FT:CT by Time Across Intervention
Note: Data presented as Mean (Standard Deviation). Floatation = Floatation-REST; Compression = PPDC.



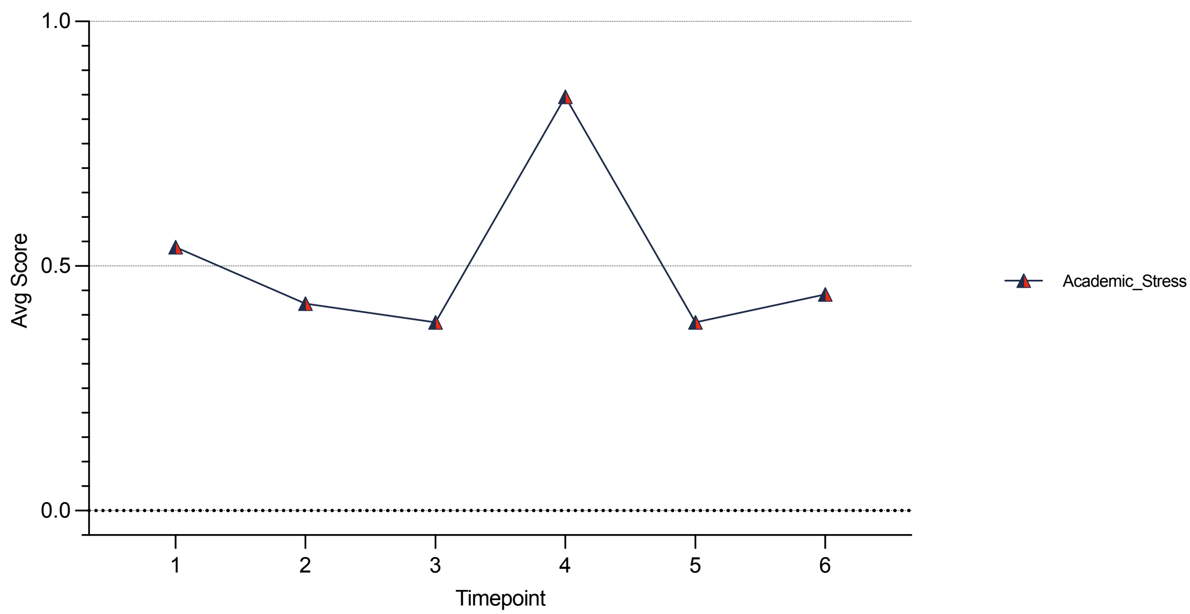
Additional Findings Figure E2.4. Mean CMD by Time Across Intervention
Note: Data presented as Mean (Standard Deviation). Floatation = Floatation-REST; Compression = PPDC.



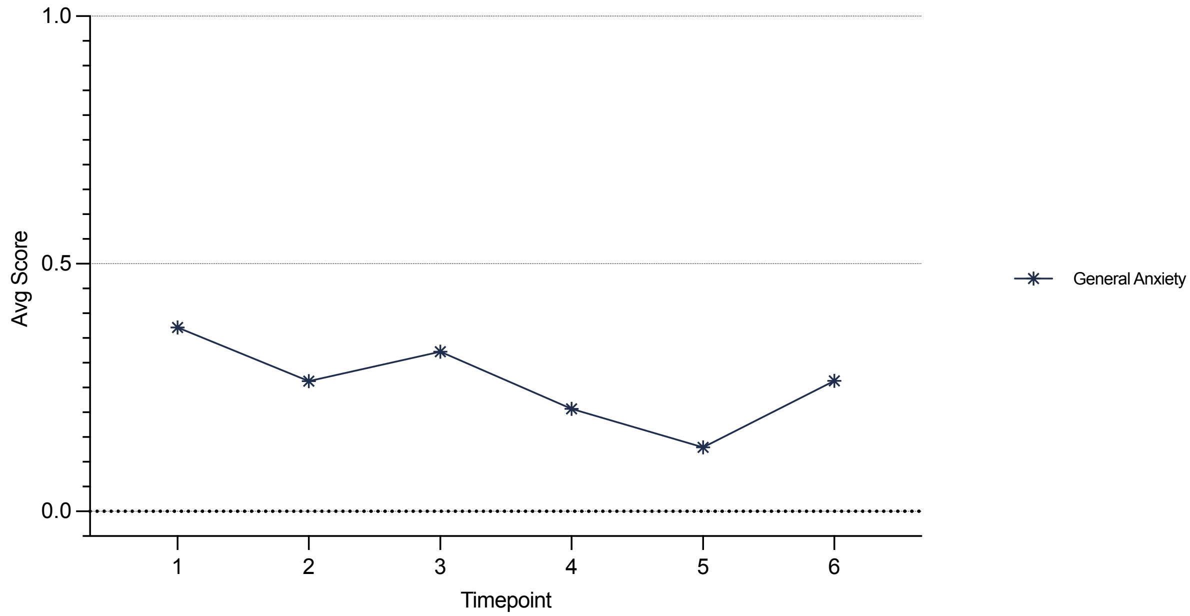
Additional Findings Figure E3.1. Individual JH Across Timepoint



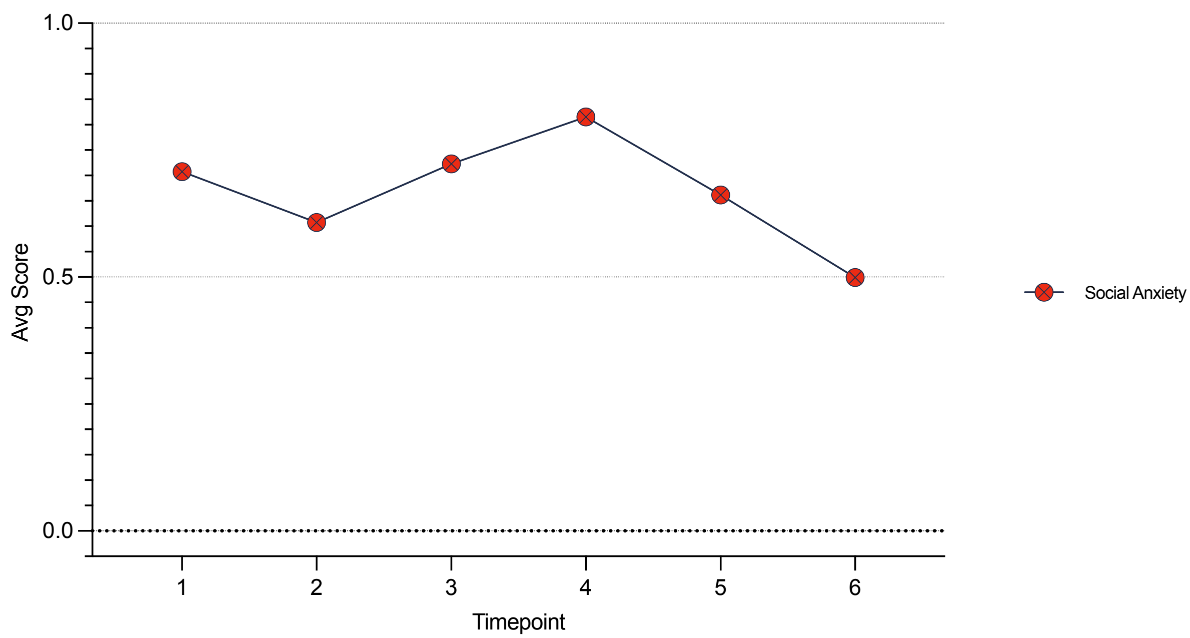
Additional Findings Figure E3.2. Individual RSImod Across Timepoint
Note: Data presented as Mean



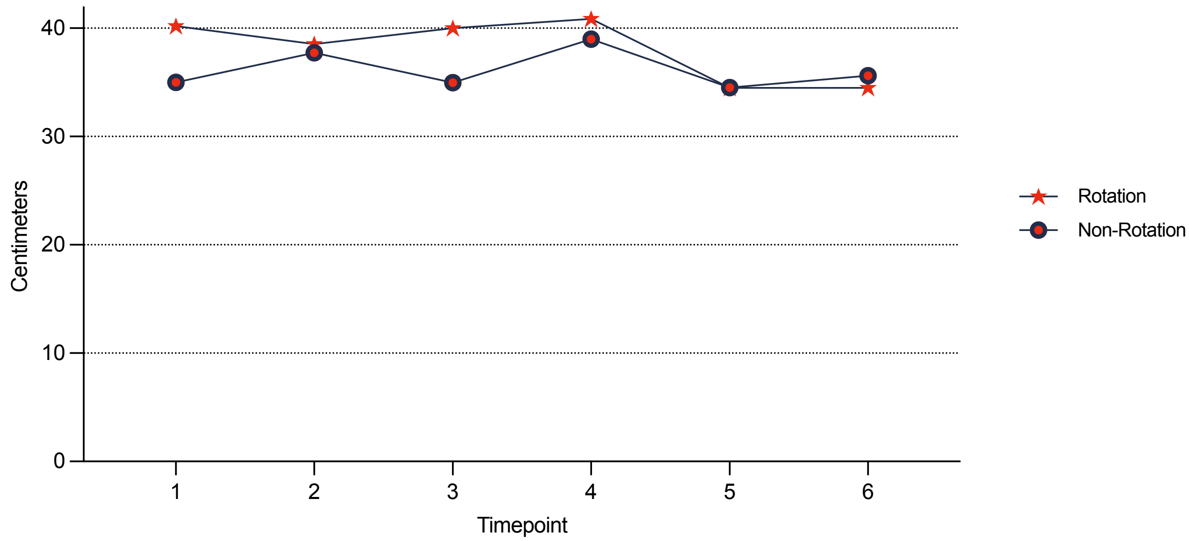
Additional Findings Figure E3.3. Mean Academic Stress Across Timepoint
Note: Data presented as Mean



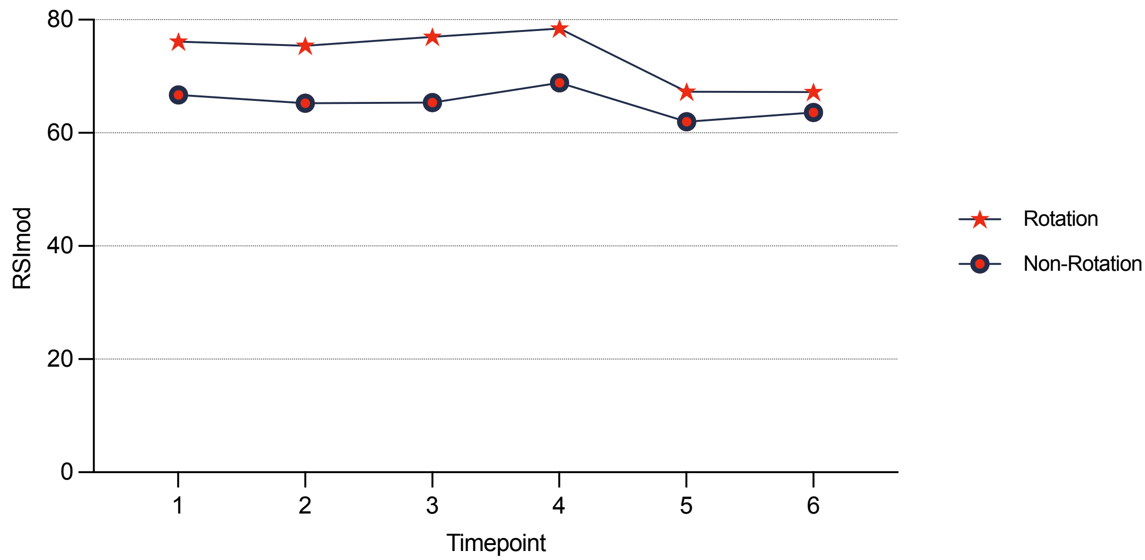
Additional Findings Figure E3.4. Mean General Anxiety Across Timepoint
Note: Data presented as Mean



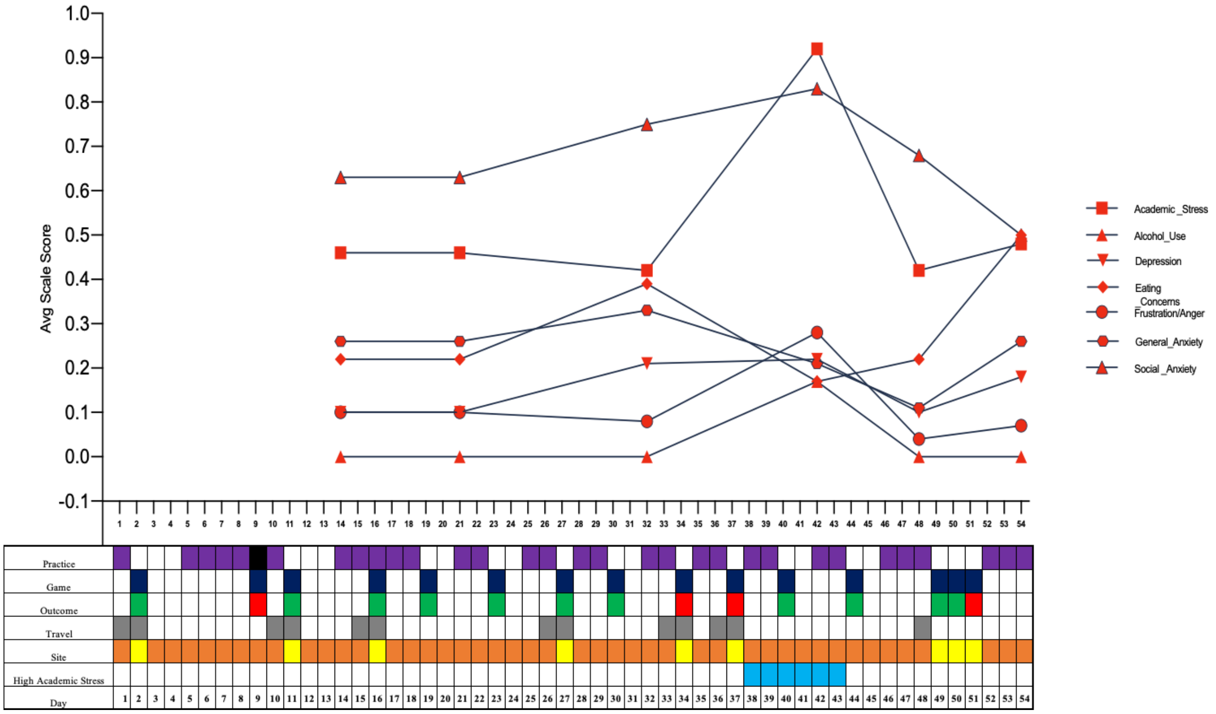
Additional Findings Figure E3.5. Social Anxiety Across Timepoint
Note: Data presented as Mean



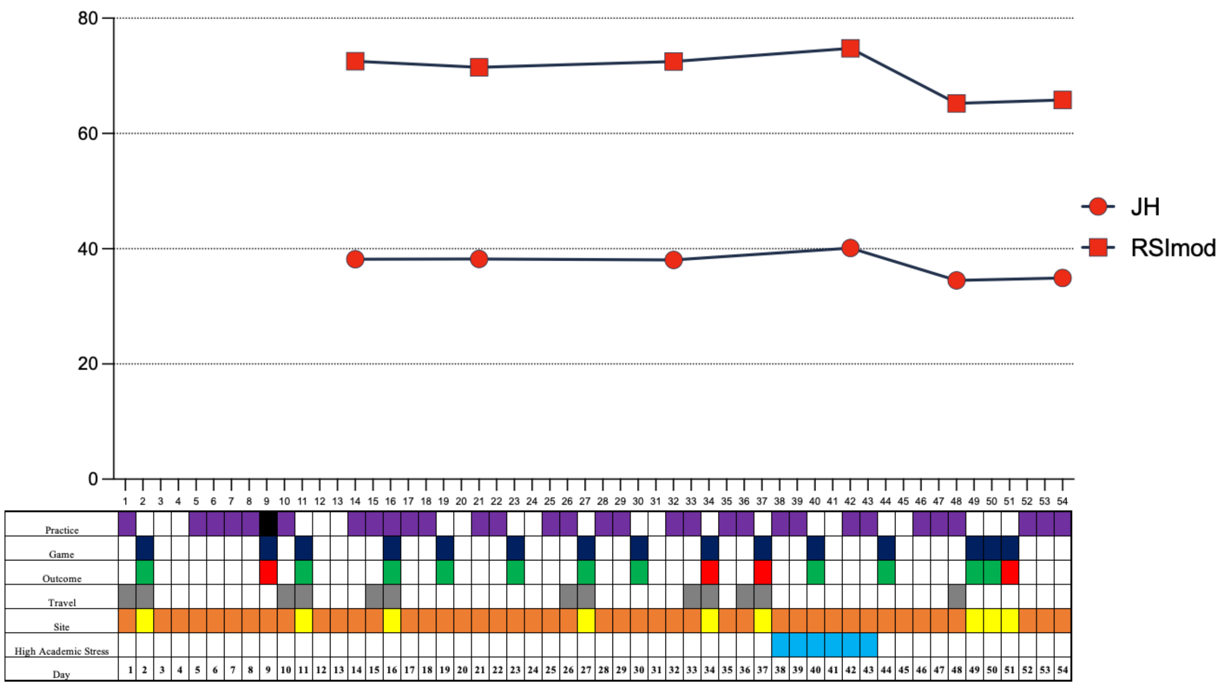
Additional Findings Figure E3.6. JH by PlayStatus Across Timepoint
Note: Data presented as Mean



Additional Findings Figure E3.7. RSImod by PlayStatus Across Timepoint
Note: Data presented as Mean



Additional Findings Figure E3.8. CCAPS-34 Across Timepoint with Contextual Data
Note: Data presented as Mean



Additional Findings Figure E3.9. JH and RSImod Across Timepoint with Contextual Data
Note: Data presented as Mean

APPENDIX F

Recommendations for Future Research

1. Multi-sport, multi-team, multi-level, and sex difference research should be conducted to examine outcomes that are generalizable beyond male collegiate basketball student-athletes.
2. Studies exploring the association between whole body accelerometry variables beyond PL (e.g., IMA decel, IMA accel, IMA COD, jump count, etc.) and countermovement jump variables.
3. Studies exploring the association of sleep quality (e.g., REM, Deep, Light, etc.) and countermovement jump variables.
4. Studies exploring the effects of other recovery treatment (e.g., cold immersion, hyperbaric chambers, photo biomodulation, etc) on neuromuscular performance.
5. Studies exploring the association between neuromuscular readiness and competitive outcomes and sport derived statistics (e.g., win/shares

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