2019

Using the Acute: Chronic Workload Ratio to Predict Peak Performance in Elite NCAA Track and Field Sprinters

Hannah Elizabeth Saylor

FLORIDA STATE UNIVERSITY

COLLEGE OF HUMAN SCIENCES

USING THE ACUTE:CHRONIC WORKLOAD RATIO TO PREDICT PEAK PERFORMANCE IN ELITE NCAA TRACK AND FIELD SPRINTERS

By

HANNAH ELIZABETH SAYLOR

A Thesis submitted to the
Department of Nutrition, Food, and Exercise Sciences
in partial fulfillment of the
requirements for the degree of
Master of Science

2019

Hannah Elizabeth Saylor defend this thesis on June 12, 2019.

The members of the supervisory committee were:

Michael J. Ormsbee
Professor Directing Thesis

Graig Chow
Committee Member

Robert Hickner
Committee Member

The Graduate School has verified and approved the above-named committee members, and certifies that the thesis has been approved in accordance with university requirements.

My thesis is dedicated to my mom for always encouraging me to pursue my dreams.

ACKNOWLEDGMENTS

Thank you to Dr. Mike Ormsbee for giving me the amazing opportunity to be a part of the Human Performance Laboratory and for your guidance, not only during the process of writing this thesis, but throughout my time at Florida State University. Thank you being an incredible example of what a researcher, professor, and mentor is.

I would like to thank Brett Hanna for his immeasurable encouragement throughout the thesis process. He was a source of strength, support, and inspiration, and I could not have done the project without him.

I would like to thank the strength and conditioning staff at Florida State University for working with me on this project and for providing me the connections and opportunities they have.

Lastly, I would like to thank my mother, Lisa Saylor, my father, Gregory Saylor, and Gustavo Cabre for their steadfast support and prayers throughout my pursuit of a master's degree and thesis project. Their presence in my life encourages me to be the best student, researcher, and person I can be.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

ABSTRACT

Purpose: To establish the relationship between the acute:chronic workload ratio and peak performance in division 1 NCAA track and field sprinters over the course of the 2018 outdoor season. ***Methods:*** The acute:chronic workload ratio was determined by calculating the sum of the week before the competition's session rating of perceived exertion of training load (acute load) and dividing it by the average weekly session rating of perceived exertion of training load over the previous four weeks (chronic workload). All ratings of perceived exertion were self-reported through an Athlete Management System (AMS) no later than one hour after the training session or competition. The sprinters' race times were recorded through an online data base and, in the primary statistical analysis, were analyzed for confounding variables. Once the confound variables were established, Pearson correlations were used covarying for the confounding variables. Our hypothesis was that there would be a positive relationship between the acute:chronic workload ratio and the 100m and 200m race times. In a secondary analysis, violating the statistical assumption of independence, the acute:chronic workload ratio was correlated to the sum of all data points for male and female 100m and 200m race times and the male and female 100m and 200m Z-scores for each sprinter. Bins were created with the hypothesis that having an acute:chronic workload ratio between 0.8 and 1.3 would be correlated with lower race times in the 100m and 200m races and more negative Z-scores for the 100m and 200m races. ***Results:*** A lower acute:chronic workload ratio resulted in a moderate positive correlation with lower race times in the 100m (R= 0.542) and 200m (R= 0.711) races. ***Conclusions:*** Maintaining an acute:chronic workload ratio between 0.8 and 1.3 may be optimal for elite division 1 NCAA track and field sprinters to reach their peak performance in the 100m and 200m races. An individualized approach to training load using the acute:chronic workload ratio should help coaches and performance staff with individualized training-load planning and prescription for the sprinters to reach peak performance.

CHAPTER 1

INTRODUCTION

Exercise is a physiological stress that disrupts homeostasis. Repeated exposure to the stress of exercise will allow for various physiological systems to adapt to the stress and improve performance (9, 17). Methods to quantify the physical adaptations an athlete experiences from repeated exposure to exercise, or training, have been sought after even before the classification of the Systems Model by Calvert et al. (15). The systems model concluded how the improved performance the athlete experiences from training occurs through an interplay between fitness and fatigue. The relationship of fitness and fatigue lead to the desire to monitor the amount of training an athlete experiences to find the balance for peak performance (15).

An athlete's workload (session RPE x session duration) completed during training sessions and competitions is referred to as training load (9, 11). Athletes respond differently to the same training load, so the ability to measure and monitor training load is important in forming training programs that will lead to peak performance (9, 11). Measuring the response to training load is achieved by monitoring both internal and external factors. Internal factors include the physiological and psychological stresses an athlete experiences during a training session or competition. Quantifications of internal training loads include heart rate, blood lactate, oxygen consumption, and ratings of perceived exertion (RPE) (8, 10, 11, 34). External factors include objective measures such as the weight moved or repetitions completed or distance traveled by an athlete during training sessions or competitions. Quantifications of external training loads include power output, speed-acceleration, time-motion analysis, global positioning system (GPS) parameters, and accelerometer derived parameters (11, 33, 38, 66, 69, 72).

The primary value in quantifying and recording internal and external training loads is to monitor the acute and chronic training loads in athletes. In team sports, a single week of training is a common way of quantifying acute workload (31). Chronic training load represents a rolling average of the most recent 28 days of training and represents a longer duration of training. Acute workload is a much shorter time period (7 days) and can be as short as one training session (52).

In Australian football players, a high chronic workload was protective against injury. However, when acute workload was greater than chronic workload, injury risk was higher and performance was decreased. An acute:chronic workload ratio of >2.0 for total distance during the in-season competition, the football players had a 5 to 8 fold greater injury risk (R^2= 5.49, P=0.016). Players with a high-speed distance acute:chronic workload ratio of 2.0 had a 5 to 11 fold greater injury risk compared to players with acute:chronic workload ratio less than 2.0 (R^2= 5.10, P=0.014) (52). These findings show that the players may not be able to handle sharp spikes in acute training during season compared to pre-season, and therefore decrease the protective nature of the chronic workload (52). In agreement with Gabbett and colleagues, multiple studies have reported a strong correlation between high chronic workload reducing the risk of injury and high acute workloads increasing the risk of injury (6, 28, 31, 35, 36).

Quantifying acute and chronic workloads is completed through the acute:chronic workload ratio, which provides an index of preparedness of the athlete and is useful in determining injury risk in athletes. The acute:chronic workload is found by dividing the last weeks (week four) workload by the four-week average. If acute workload is low and chronic workload is high, the ratio will be less or close to one and is correlated to lower risk of injury. If acute workload is high and chronic workload is low, the ratio will be greater than one and is correlated with higher risk of injury (31). Using heart rate monitors or GPS devices are ways to quantify external workloads over four weeks. However, in team sports, session rating of perceived exertion (sRPE) is the most validated way of quantifying training load as it combines the principles of Borg's modified RPE scale (1 to 10) and the acute:chronic workload ratio (73). sRPE is found by multiplying session time by the RPE rating from the 1-10 scale. sRPE has been shown to correspond with heart rate and blood lactate markers of exercise intensity (26). Foster and colleagues have validated sRPE for being successful in monitoring training load in a variety of exercise modes (27, 48, 62, 70, 73). Using sRPE and the acute:chronic workload ratio can be used to predict how ready an athlete is to perform. It has been proposed that using session RPE provides accurate feedback from athletes on actual internal training load and strain vs. desired training load. It is a valid, reliable, minimally invasive, and easy to collect method of monitoring training load (23). To our knowledge, there is no research using the acute:chronic workload ratio as a training load management in elite track and field sprinters. There is also no research using the acute:chronic workload ratio (sRPE) to predict performance as most of the previous literature exists primarily in relation to injury.

1.1 Purpose

The purpose of this investigation was to use session RPE to correlate acute:chronic load ratio to peak performance in elite division 1 NCAA track and field sprinters during the outdoor season of 2018.

1.2 Aim and Research Hypothesis

1.2.1 Aim 1

To determine the correlation between acute:chronic workload ratio (using session rating of perceived exertion (sRPE)) and peak performance in competition for elite division 1 NCAA track and field sprinters.

Hypothesis for Aim 1: We hypothesized that the sprinters who had an acute:chronic workload ratio 0.8 to 1.3 the week before a competition will have improved performance in competition compared to the sprinters who had an acute:chronic workload ratio over 1.5.

1.2.2 Assumptions

The following assumptions will be made in this investigation:

1) Participants accurately filled out a daily questionnaire reporting wellness and session RPE for the training sessions.
2) Mechanical efficiency apart from injury was similar for the sprinters.
3) All athletes attempted to perform their best at all competitions.

1.3 Delimitations

Delimitation will include the following:

1) The track athletes were sent the session RPE questionnaire one hour after practice was completed.

1.4 Limitation

The limitations of this study include:

1) These data were collected on one team with seven sprinters, therefore the data may not be generalized for all track athletes.
2) These data were collected on division 1 NCAA track and field sprinters and may not be transferable to other division athletes.
3) That these data were collected in track and field sprinters and may not be generalized to all athletes.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Defining Training Load

2.1.1 Training Load Defined

Training load is the quantification of the work performed by an athlete or group of athletes during the training sessions and competitions. Measuring an athletes response to the workload is achieved with a unique combination of internal and external factors (11). Internal training loads are defined as the relative biological stressors, which includes both physiological and psychological, the athlete experiences within the training session or competition. Quantification of internal training loads includes heart rate, blood lactate, oxygen consumption, and ratings of perceived exertion (RPE). External training loads are objective measures such as the work performed by the athlete in competition or training sessions (11). External training loads are measured separately from internal workloads. Metrics used in measuring loads include power output, speed-acceleration, time-motion analysis, global positioning system (GPS) parameters, and accelerometer derived parameters. It is important to have an integrated approach to training load because the athlete experiences both internal and external factors during the training session and competitions. Understanding internal and external training loads provides greater insight to how an athlete responds to training stress, which allows coaches and training staff the ability to create a more effective training program for the athlete (11).

2.1.2 Importance of Monitoring Training Load

Load monitoring informs a coaches' decision making on an athletes' ability to train with the goals of creating a training program that reduces injury rates and leads to performance enhancement. Internal and external monitoring can provide data on the consequences of training (60), identify fatigue levels after competition (2, 40), and identify changes in fatigue or fitness status (12). Training load monitoring allows open communication between the coach and athlete where both can provide feedback on current training (11).

Monitoring training loads can lead to enhanced athletic performance by maximizing the athlete's opportunities to train and therefore improve their condition and skills. Performance is difficult to measure because performance responses to training are non-linear and are influenced by both non-training and training-related factors. Even though research is limited on the accuracy of using methods that monitor training load to predict performance in elite athletes, the methods still provide an important theoretical framework that allows scientists and coaches the ability to better understand and control the training process (11)

Monitoring training loads can also be helpful in reducing injuries by avoiding inappropriate training load (28). Gabbett et al. (28) examined the influence of perceived intensity, duration, and load of matches/training on injury of 79 semi-professional rugby league players. These authors reported that more training injuries were sustained in the first half of the season (first vs second: 69.2% vs 30.8%, $P < 0.001$) which coincided with increased training load. Similarly, match injuries occurred more frequently in the latter stages of the season (53.6% vs 46.4%, $P < 0.001$) when match load was at its greatest. A significant relationship ($P < 0.05$) was observed between changes in training injury incidence and changes in training intensity ($r = 0.83$), training duration ($r = 0.79$) and training load ($r = 0.86$). In addition, changes in the incidence of match injuries were significantly correlated ($P < 0.05$) with changes in match intensity ($r = 0.74$), match duration ($r = 0.86$) and match load ($r = 0.86$). These findings suggest that as the intensity, duration and load of rugby league training sessions and matches is increased, the incidence of injury is also increased (28).

Gabbett et al. (29) have also reported that lower pre-season training loads reduced training injury rates in rugby league players and resulted in greater improvements in maximal aerobic power during pre-season and continuing into the season during the 2001-2003 seasons. The training loads (in hours) for the 2002 (1165.9) and 2003 (1478.9) pre-season periods were significantly lower ($p < 0.001$) than those in 2001(1442.4). The incidence of injury was significantly higher (x2 = 44.3, $p<0.001$) in the 2001 pre-season period (156.7 per 1000 training hours, 95% CI: 136.3 to 177.1) than the 2002 (94.4 per 1000 training hours, 95% CI: 76.7 to 112.0) and 2003 (78.4 per 1000 training hours, 95% CI: 64.2 to 92.7) pre-season periods. There were no significant differences in the incidence of injury between the 2002 and 2003 pre-season periods.

The increases in maximal aerobic power steadily improved across the three seasons with a 62–88% probability that the 2002 and 2003 pre-season improvements in maximal aerobic power were of greater physiological significance than the 2001 pre-season improvements in maximal aerobic power (29).

2.1.3 Internal Training Workload Quantification

Internal workloads reflect how the athlete is responding biologically to the training session or competition. There are multiple ways to quantify internal workloads within the athlete. Heart rate, blood lactate, other biochemical markers such as cortisol, oxygen consumption, and ratings of perceived exertion (RPE), questionnaires, or Profile of Mood States questionnaire (POMS) are commonly used to assess internal load (10). Using questionnaires and diaries to assess regular physical activity and wellness in team sports is common because the methods are easy, cost effective, and do not interfere with training. Both questionnaires and diaries are used to measure physical activity during the past week, month, or year. Both also account for some external variables such as environmental factors that affect motivation, physiological, and physical effects. However, it must be noted a limitation to any questionnaire is the subjective nature of the data collection (8, 34).

O'Connor et al. (54) conducted a Profile of Mood States questionnaire (POMS) and obtained resting salivary cortisol concentrations in 14 female collegiate swimmers and 8 active college women who were controls. Both quantification methods were used since POMS is a psychological marker, or internal method, and cortisol is a physical marker, or external method, important in determining an athlete's competitive preparedness. Salivary cortisol has been determined to be an efficient tool for monitoring the effects of training. Training load baseline was 2,000 yards/day in September to a peak of 12,000 yards/day in January followed by a taper to 4,500 yards/day in February. Specifically, the swimmers experienced significant ($p < 0.01$) negative changes in depression, tension, energy, anger, fatigue, and global mood across the training season compared to the controls. Salivary cortisol was significantly ($p < 0.01$) greater in the swimmers compared to the controls during baseline and overtraining but was not different between the groups following the taper. Salivary cortisol was significantly correlated with depressed mood during overtraining ($r = 0.50$; $p < 0.05$), but not at taper or baseline (54).

2.1.4 External Training Workload Quantification

External workloads are measured objectively and independently from internal workloads. The most common measurement of external training load in elite team sports is derived from the use of a global positioning system (GPS) device. GPS devices measure distance calculated by positional differentiation, which takes the GPS location and compares the location to a known location then calculates the difference which accounts for variance in speed (69). Velocity is calculated via the Doppler-shift method, which is the change in frequency or wavelength of a wave for an observer who is moving in relation to a related source (33, 69). The Doppler-shift method results in better precision and fewer errors than calculating velocity from distance. Speed is then calculated from changes in the given GPS distance divided by the time between each logged position (11, 69). Elite Australian football players (n=20) were studied to identify the accuracy of GPS devices (38). The athletes wore two GPS devices and completed straight-line movements (10, 20, 40 meter (m)) at various speeds (walk, jog, stride, sprint), changes of direction at two different frequencies, and a team sport running circuit. The athlete's position and speed data were collected by the GPS devices at 1 and 5 Hz (Hz is the measure of frequency). It was reported that the GPS accuracy decreased as speed of locomotion increased in both straight line and the change of direction courses. Difference between criterion and GPS measured distance ranged from 9.0% to 32.4%. A higher sampling rate improved validity regardless of distance and locomotion in the straight line, change of direction and simulated running circuit trials. The reliability improved as distance traveled increased but decreased as speed increased. Total distance over the simulated running circuit exhibited the lowest variation (coefficient of variation: 3.6%) while sprinting over 10 m demonstrated the highest variation (coefficient of variation: 77.2% at 1 Hz) (38). Overall, GPS as a measure of external workloads is valid and reliable as long as acceleration, deceleration, and directional changes are measured with room for variation when distance is accounted for (11, 38, 66, 72).

Other measures of external workload include multimeter, computer-based time-motion analysis, and accelerometer derived parameters like speed acceleration. These other measures are not used as often as GPS and vary depending on the mode of exercise (11).

2.1.5 Current Perspective on Quantifying Training Load

As time has evolved, the approach to quantifying training load has grown from using stopwatches to more precise measures. Most models that quantify training load in hopes of linking training and performance consider the athlete as a system where training load is the input and performance is the output (10). Even though more research is warranted on each of the current methods to measure training load, coaches often choose to quantify training load through diaries, questionnaires, physiological monitoring, and direct observation (10). In search of quantifying training stress, coaches typically will observe training impulses (TRIMP) and session rating of perceived exertion (sRPE). TRIMP is a method proposed by Banister et al. (4) where they suggested that a person's heart rate response to exercise, along with exercise duration make up a training impulse. sRPE is a rating of overall difficulty of the exercise session obtained 30 minutes after the completion of the exercise (10, 25). Although Session RPE and training impulse may prove to be useful tools in recording physiological adaptations to training, their influence on performance has not been accurately quantified due to limited research (10, 34, 67). However, conducting research on the frequency, duration, and intensity of exercise is extremely valuable because peak performances require an understanding of how the quantifiable effects of training influence performance in order to create an optimal training program (9, 34).

Optimizing training begins by quantifying what the athlete is currently doing. Both internal and external quantification methods are used to determine an athlete's performance status. The next step in optimizing training is understanding the athlete's ability to undergo certain levels of exertion. The use of measures like sRPE and training impulse (TRIMP) can help quantify an athlete's level of exertion. Once the current level the athlete is training at and the highest training load the athlete can sustain are determined, an optimal training load can be defined in a specific terms (9).

2.2 Historic Quantification of Workload

2.2.1 The Systems Model

One question that has been debated since the early 1970's is: how does training modify performance throughout the whole training period? The traditional problem has been finding a model that addresses both quantification of training and performance. Past research has concluded that performance appears to be related to the difference between fitness and fatigue, but the issue of how to quantify fitness and fatigue still remains. The search has been for a model that would be able to reflect an athlete's response to extremely intensive training and "tapering" and also explain the connection of the training to performance. Calvert et al. were the first to propose the Systems Model for training in athletes. The Systems Model consists of four components: endurance, strength, skill, and psychological factors (15).

The basis for the four component Systems Model was the observed need to include more dynamic responses to training. Previously, the observed relationship between performance and training was seen through a mathematical approach. As the athletes training increases moderately, *w(t)*, a limited rise in performance, *p*, with a time constant, *T*, of 30-50 days (d) is seen. As training continues to increase, the increase in performance would be proportional to the difference between the potential maximal performance determined inherently and the current performance level, *p(t)*, attained by the athlete. After continuous training stops, performance will decrease exponentially back to a lower level. From the observed relationship, a simple first order differential equation was formed (15).

$$\frac{dp(t)}{dt} + \frac{1}{T}p(t) = w(t)$$

The corresponding transfer function is:

$$G(s) = \frac{P(s)}{W(s)} = \frac{1}{s + 1/T}$$

And in terms of convolution:

$$P(t) = w(t) * g(t)$$

$$= w(t) * e^{-1/T}$$

Equation 1. Corresponding transfer function of the systems model (15)**.**

Where * indicates convolution, *g(t)* is the impulse response $e^{-1/T}$, and *T* is the time constant (30-50 days). When the *T* constant exceeds 50 days and is closer to 150 days of training, the equation showed correlation between a decrease performance and the observed effects of overtraining. However, the major issue with simply restricting the relationship between training and performance to a simple mathematical equation is that the equation does not account for the active response a person has to training (4, 15).

The four component Systems Model was the first multicomponent model that sought to explain effects of different factors (endurance, strength, skill, and psychological) of training on performance. Endurance involves the respiratory, cardiovascular, and cell metabolism systems. To sustain work, the muscles use aerobic process (oxygen used to utilize the energy stored in glycogen) (15). One aim of endurance training is to increase oxygen supply since the level of performance is limited by the rate of oxygen supply to the cell. Oxygen supply can be limited by the lungs, cardiac output, the number of red blood cells, and by peripheral circulation of the blood to the muscles (63). Since the body sends additional blood to active muscles, the heart rate observed when performing exercise provides and indirect measure of aerobic performance (43). Stroke volume is the amount of blood ejected from the ventricles during one systole. It is the difference between end-diastolic and end-systolic volumes. Stroke volume increases to a heart rate of approximately 110 beats per minute (bpm) and above 110 bpm it is at the maximal level. Cardiac output is the product of strove volume x heart rate. Heart rate influences ventricular filling time and stroke volume so that changes in cardiac output caused by changes in heart rate are attenuated (61). Some endurance exercise results in heart rate over 110 bpm, so increase in output is due to heart rate rather than stroke volume. Therefore, heart rate can be used as an indirect measure of aerobic performance (43, 61). The time constant in **equation 1** is 30-50 days for performance increases to be recognized as the aerobic adaptations of heart rate, stroke volume, and cardiac output develop (13, 42).

Strength of the muscles can be increased by functional hypertrophy and improving neural organization for recruiting muscle fibers mainly through resistance training. During hypertrophy, contractile elements within the muscle enlarge and the extracellular matrix expands to support growth. Hypertrophy can occur by adding sarcomeres in series or in parallel. When the skeletal muscle is subjected to an overload stimulus, the stimulus causes disruption in myofibers and in the related extracellular matrix. The disruption causes a chain of myogenic events that ultimately leads to an increase in size and amounts of the myofibrillar contractile proteins actin and myosin, and the total number of sarcomeres in parallel, increasing the muscles cross-sectional area (65). The central nervous system (CNS) controls resistance-trained muscles better than non-trained muscles. The resistance trained muscles have an increase in their force-generating capacity. If each motor unit within a muscle is capable of producing more force after training, fewer motor neurons need to be recruited to elicit a large recruitment of muscle fibers (16, 18). Strength training is an important factor in the systems model and the time constant for performance improvement in **equation 1** is 20-40 days. With disuse, CNS control of the muscles will decrease and muscle strength will decrease as the muscle is no longer experiencing a stimulus to induce hypertrophy (15, 16, 18, 65). Skill is important in activities like high jump or javelin throwing and unimportant in other activities like long-distance running. With an increase in physical training of specific skills, the learning curve for the skills increases as well. Psychological factors refer, in part, to the athletes' motivation to perform. Increase in motivation can increase performance, but an increase in motivation can also cause an increase in overtraining. The Systems Model is applicable to specific individuals, type of performance, and type of training (15).

2.2.2 Fitness and Fatigue Model

A case study was conducted on fourth year swimmers for a university testing the application of the four component Systems Model. The swimmers participated in flexibility exercises and weight exercise to develop strength and swimming power. Swimmers were asked after every training session how they felt. The most interesting finding was how the interplay between fitness and fatigue affected overall performance (15). Banister et al. proposed an equation to assess the training effect (dose) on performance (response) to establish a quantifiable relationship between training load and performance (**equation 2)** (4, 9, 15):

Model performance=(fitness from training model)- K(fatigue from training model)

$$A(t)= k_1 w(t)e^{-t/T1} - k_2 w(t)e^{-t/T2}$$

Equation 2. Calculation for training effect on performance (4).

where *K* (1 for fitness and 2 for fatigue) is the constant that adjusts for the magnitude of the fatigue effect relative to the fitness effect, w[t] is the training impulse, and k1 and k2 are weighting factors (initially k1 = 1 for fitness and k2 = 2 for fatigue). The fitness impulse (k1w[t]) and the fatigue impulse (k2w[t]) can be calculated by multiplying the training impulse (w[t]) by the appropriate weighting factor (k_1 or k_2) (4, 10, 15). Fatigue was measured in terms of a deficit in the endurance and strength categories. Since fatigue had a dominant effect on performance, it can be said that a deficit in an athlete's endurance and strength is the reason for lower performance (15).

Equation 2 includes two functions where one represents a negative influence on performance and the other represents a positive influence on performance. Between training sessions, the fitness and fatigue variables decline exponentially but at different rates. Sudden spikes in training lead to fatigue rather than a gain of fitness. Nonetheless, the decay time constant of fitness is longer. Banister et al. (4) suggested that the fitness decay time constant (t_1) may be estimated initially as 45 days and the fatigue decay time constant (t_2) as 15 days. With the initial values for the weighting factors (k_1 = 1 and k_2 = 2), the time constants are only estimates that allow for a prediction to be made of future performance. Data from real performances are then collected and compared with the predicted performance, and the decay time constants and weighting factor constants adjusted if inconsistencies occur between the predicted and real performance (4, 10).

Calvert et al. (15) conducted a case study on a collegiate swimmer using the systems model over the two seasons (1970- 1971 and 1973-1974) he participated in swimming at university. The swimmer underwent a regular training program of flexibility exercises, weight exercise, and swimming. The swimming consisted of a warm up (500m), low-quality activity (long distance- 3000-5000m) and high-quality (short distance swam quickly with long rests in between e.i.100m at intervals of three or four minutes). The swimmer was asked RPE at the end of each session. In the first season, the criteria for performance of the swimmer was taken to be his best time to swim 100-m time trials.

The difference between the two charts can be explained by the athletes training load. The swimmer swam up to 12,000 meters per day for several weeks and experienced serious fatigue measured by decrease in performance. **Figure 1** shows the time function for fatigue and fitness in response to the training impulses. When comparing the modeled performance for the 1970- 1971 season and the 1973-1974 season, the additive constant a(*t)* was reduced from 66.5 to 55.5

showing the improvement in the swimmer's level of performance. The effect of the fatigue function on performance was almost the same between two seasons (multiplying constants are 0.017 and 0.015). This was not expected since the swimmers are more fit in the later season (1973-1974). The effect of fitness function (**equation 2)** on performance is about four times less in the later season (results from **equation 1** 0.0017 compared to 0.0075). This indicates that training has less effect on the fitness of the swimmer who is already very fit. Linking performance to the systems model showed the model can be applied to athletes and be useful in quantifying training load (15). Busso et al. (14) later tested the accuracy of a simplified form of the above model, comprising only the fitness impulse [$a(t) = w(t)k_1e^{t=t1}$]. They reported that it produced a similar fit of estimated and real performances, accounting for 61–87% of the total variation in estimated and actual performances (10, 14).

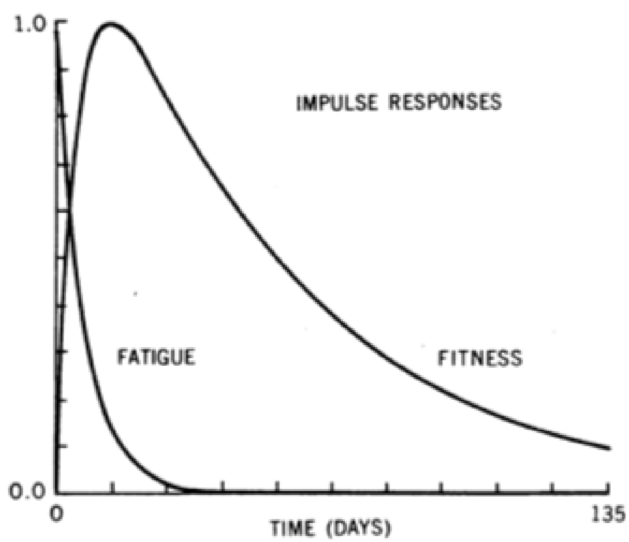

Figure 1. Impulse responses used for fitness and fatigue function (15).

Even though the fitness and fatigue model has been criticized for oversimplifying the complex relationship between training load and performance, the approach provides a basis to set future training loads and recovery periods and allows coaches to understand to general responses of athletes to training. The interplay between fitness and fatigue results in impulse-response models that relate training loads to performance and accounts for the dynamic and time-based characteristics of training and the effects of training over time (4, 10, 11, 15).

2.2.3 Perceived Exertion as an Indicator of Physical Strain

Borg discovered a way to quantify subjective measures, and how they relate to objective findings. The basis for his search of a method to quantify workload was the observation that most people seek medical treatment when they observe a severe decrease in physical working capacity and have an increase in subjective strain. Borg believed that perceived exertion is the single best indicator of physical strain. Other measures of physical strain include blood chemistry like total blood count, creatine kinase, uric acid, urea, C-reactive protein, and ferritin as well performance markers like vertical jump height, maximal velocity, and recovery stress questionnaires (1, 23, 48, 49). From the need to quantify perceptual intensities, “ratio-scaling methods” were created where the methods had the same metric makings as methods used in physiology, where there is an absolute zero with the same distance between all scale values. However, the major issue with the ratio-scaling methods are that the methods do not provide direct levels for comparisons between individuals (7).

2.2.4 Borg’s Rating of Perceived Exertion (RPE) Scale

To address the challenges with the ratio-scaling methods, Borg created a scale for ratings of perceived exertion. His first scale was a 21-grade scale containing verbal anchors that represented previous RPE scales that used verbal anchors to assess subjective perception but did not have any metric value. An advantage of the category scale is its usefulness for direct individual comparisons since the person responds to the stimuli in a more absolute way, meaning it is specific to that person only (7).

After his first scale, Borg created a new category scale for RPE rating to increase linearly with the exercise intensity for work on cycle ergometer. Oxygen consumption and heart rate increase linearly with workload, so if RPE also increased linearly with workload, it would be useful way to construct a scale. The RPE scale (**Table 1**) scale range from 6 to 20 and are a reflection of heart rates ranging from 60-200 beats/minute. The correlation of heart rate should be approached with some caution as the values may indicate different strain based on age, type of exercise, exertion, environment, and other factors. However, many studies show correlations of the ratings from the scale and heart rate range from 0.80-0.90 (53).

Scherr et. al. (64) had male and female participants complete incremental exercise testing on a treadmill or cycle ergometer. Rate of perceived exertion, blood lactate concentration, and heart rate were taken at the end of the test to quantify workload. Rate of perceived exertion was strongly correlated with heart rate (*r=0.74, p<0.001)* and blood lactate (*r=0.83, p<0.001).* It was concluded that Borg's RPE can be practical, cost effective, and valid tool for prescribing exercise training load and intensity independent of age gender, exercise modality, physical activity level, and cardiovascular disease (64). Words accompany numerical rating allowing the athlete to quantify the meaning of the numbers. The words "somewhat hard" correlate with what would be "moderate" exercise (130 bpm) and are in the middle of the scale. Symmetrically on either side of the middle, words correlating with "weak" and "strong" are "very" and "fairly." The words transform the scale from an interval scale to a category scale since the values increase linearly (7).

Table 1. Borg's rating of perceived exertion (RPE) scale (7).

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

2.2.5 Use of Borg's RPE Scale

Category expressions may not be as mathematically accurate as a ratio scale, but category scales provide more context, giving the ratings more applicable significance than a ratio scale values. Category scale expressions are grounded in certain "population norms" or "experimental values" giving accurate inter-individual meaning to the work performed. The verbal expression given to report perceived exertion (**Table 1**) by a subject running on the treadmill or cycling on an ergometer in a laboratory setting depends more heavily on sensory signals than the cognitive frame of reference. The physical stress each participant feels while performing work depends purely on his or her capacity relative to each participant's "absolute" range. The category scale Borg developed is a range-model, which indicates a fundamental principle for inter-process comparisons such as exercise exertion between walking and running for the same person (7).

RPE can be useful outside of the laboratory as well. When creating exercise prescriptions, RPE can be a valuable marker of exertion rather than using heart rate. Assigning someone to work at a specific heart rate can limit the person's ability to exercise because one day 130 beats per minute (bpm) may feel easy and the next day 130 bpm will feel extremely difficult. Using RPE may help quantify a person's risk for injury or strain while working at a specific workload (7). In older adults undergoing exercise, it was reported that oxygen uptake (VO_2) ($p<0.01$) and HR ($p<0.01$) increased linearly with RPE showing that RPE is an accurate tool to use in exercise prescription (46).

The American college of Sports Medicine (ACSM) recommended the rating of perceived exertion as a significant means of monitoring exercise intensity during graded exercise testing and controlling exercise intensity during endurance training (47). RPE exertion levels of 12 to 16 on Borg's RPE Scale are claimed to be equivalent to between 50 to 85% of a person's VO_2max (5). Currently, RPE is included in the ACSM's Exercise Testing and Prescription best practices for monitoring during a symptom-limited maximal exercise test along with electrocardiogram, heart rate, blood pressure, and signs and symptoms (47).

2.2.6 A New Category with Ratio Based RPE

Over time, a new category scale was developed by Borg with ratio properties. The main notion is that the numbers should be anchored by verbal expressions that are simple and easy to understand by most people (7). Expressions are placed on the ratio scale according to their quantitative meaning. The verbal words quantify the numerical number meaning if “light” quantifies 4, then “very light” should quantify 2. The new category scale with ratio properties range from 0-10 with 10 as “very, very heavy” and 0 as “nothing at all.” The new category scale (**Table 2**) is mainly used for the heaviest exercise or physical work perceived by the subject like lifting weights or running. It is not known if there is one perfect scale to address all types of subjective intensities in all types of situations. The first scale presented by Borg best fits simple applied studies, exercise testing, and prescriptions of exercise intensities. The new category scale is more applicable in field situations (7).

Table 2. The new rating scale constructed as a category scale with ratio properties (7).

0	Nothing at all	(Just noticeable)
0.5	Very, very weak	
1	Very weak	
2	Weak	(Light)
3	Moderate	
4	Somewhat strong	
5	Strong	(Heavy)
6		
7	Very Strong	
8		
9		
10	Very, very strong	(Almost max)
• Maximal		

2.3 Current Physiological Methods to Quality Training Workload

2.3.1 Physiological Effects of Exercise Training

Exercise is a stimulus that causes a disturbance in homeostasis. Homeostasis is then restored after the training session during recovery. The body's efficiency to return to homeostasis after a training is altered after several training sessions, so that subsequent exercise at the same intensity may cause less disturbance to homeostasis then before training began. Optimal training adaptations are produced when training load and recovery are balanced so the athlete's physiological systems are adequately stimulated to adapt and recovery is not diminished. Because a method to determine balance between training load and fatigue is highly sought after, methods to quantify training workload have been developed (10, 24, 42, 71).

2.3.2 Oxygen Consumption

Oxygen consumption (VO_2) is a valuable measure in steady state exercise. The steady state concept implies that the oxygen flow and carbon dioxide flow are equal at each level along the respiratory system during exercise. VO_2 is a measure of steady state exercise because the relationship between oxygen consumption (VO_2) and steady state workload is linear, meaning as the workload increases, VO_2 increases (22, 62). The VO_2 response to exercise is a function of exercise intensity and can therefore be divided into three domains. The first domain is called moderate exercise or moderate intensity because it does not elicit a significant increase in blood lactate. The upper limit of the first domain is called the lactate threshold or anaerobic threshold. The second domain is heavy exercise. Heavy exercise is quantified as an exercise intensity above lactate threshold. Lactate production is greater than blood lactate clearance, but the lactate levels can be stabilized if the work rate is below the maximum lactate steady-state. The third domain is severe intensity where work rate is above the maximum lactate steady-state and results in a systemic increase in blood lactate (55, 75, 76).

In moderate exercise, three phases of the exercise VO_2 occur. Phase 1 represents the quick increase in VO_2 within the first 15 to 25 seconds of exercise. Any changes in venous O_2 content from the active muscles may not arrive in the lungs and do not affect phase 1 VO_2 kinetics.

Phase 2 reflects the influence of muscle metabolic change on VO_2 measured at the mouth. After a short delay of phase 1, VO_2 increases exponentially to a steady state level. Neither the slop of the increase in VO_2 with respect to work rate or the VO_2 time constant have been found to be a function of work rate indicating a linear dynamic relationship between the VO_2 and work rate. Phase 3 is steady-state VO_2 levels and can be seen after 3 minutes. During phase 3, VO_2 increases linearly with work rate with a gain of 9 to 11 ml/O_2/watt/ min during moderate exercise (10, 55, 75, 76).

Another use of oxygen consumption as a method to quantify training is VO_2max. VO_2max is the maximum consumption measured during incremental exercise. VO_2max test fully exhausts the aerobic energy system through increasing intensity at set workloads on a treadmill or cycle ergometer in a laboratory setting using a metabolic cart.

The test measures ventilation, oxygen and carbon dioxide concentration for the inhaled and exhaled air. VO_2max is reached when oxygen consumption remains at a steady state despite an increase in workload (19). VO_2max can be expressed either as an absolute rate in liters of oxygen per minute (L/min) or as a relative rate in milliliters of oxygen per kilogram of body mass per minute (mL/kg . min). Relative VO_2max rather than absolute VO_2max is more commonly used to compare the exercise intensities completed by endurance athletes because has been found that VO_2max is exercise mode specific, so VO_2max needs to be determined for each mode before exercise can be prescribed or quantified using relative VO_2 values (19, 34, 41).

VO_2max is properly defined by the Fick equation (**equation 3)**:

$$VO_2max = Q \times (C_aO_2 - C_vO_2)$$

Equation 3. Fick equation using values obtained during maximal exertion at maximal effort.

Where Q is cardiac output, C_aO_2 is the arterial oxygen content, C_vO_2 is the venous oxygen content and ($C_aO_2 - C_vO_2$) is the arteriovenous oxygen difference (21). Approximations of VO_2max through submaximal tests where the level of effort is limited to submaximal exertion.

Submaximal exercise tests require clients to perform a fixed amount of work per unit of time (44).

2.3.3 Lactate

Assessment of the accumulation of blood lactate during exercise and following exercise is a common measure of exercise intensity (9). Blood lactate levels are reflective of the contribution of anaerobic metabolism towards exercise. Elevated blood lactate levels are indicate greater contribution of anaerobic metabolism and as such a higher intensity of exercise (59). Even though the measurement of blood lactate concentration has become easier over time, measuring lactate frequently during every training session to prescribe or quantify intensity is impractical because it is invasive (59).

The intrinsic intra- and inter-individual differences of how much or how fast lactate accumulates during exercise are two major limitations of the use of lactate to prescribe exercise training load. Other factors such as ambient temperature and dehydration may influence the interpretation of lactate measurements. Mode of exercise can also influence lactate, as it alters the muscle mass used during exercise such that the same lactate concentration occurs at different VO_2 levels during running and cycling. Exercise duration and intensity may also influence lactate concentration leading to more limitations in using lactate concentration for quantifying training load (10, 37, 68).

2.3.4 Heart Rate

Using heart rate to quantify training load is based on the observed principle that the relationship between heart rate and steady state work rate is linear (34, 62). Heart rate is a sound measure of internal workload, but the access to heart rate monitors or the use of heart rate monitors in daily practice may be a limitation. Percent maximum/competition heart rate has been used to prescribe exercise intensity (34), but the Karvonen Method is more commonly used in prescribing intensity. The Karvonen Method is a mathematical equation that is used to determine a target heart rate training zone. The Karvonen Method uses maximum heart, resting heart rate and desired intensity to find the heart rate an athlete should be at to match the prescribed intensity (**equation 4)** (10, 39).

$$\text{Target Heart rate} = \underline{((\text{max HR- Resting HR}) \times \% \text{ desired exercise intensity}) + \text{resting HR}}$$

Equation 4. Karvonen Method formula.

Where % intensity is the prescribed intensity, HR_{rest} is resting heart rate and HR_{max} is maximal heart rate.

2.3.5 TRIMP Method

Many different methods have been formed for quantifying internal workload based on heart rate. Banister et al. proposed a method for quantifying a training session into a "dose" of physical effort where the "dose" is the unit. A person's heart rate response to exercise with the exercise duration could be used as a measure of physical effort since it is based on how exercise causes a physiological rise between resting and maximal levels in response to intensity. The combined heart rate response and duration of exercise was called training impulse (TRIMP). A training impulse (TRIMP) is calculated (**equation 5**) using maximal heart rate, heart rate at rest, the average heart rate during exercise, and exercise duration (4, 10).

$$\text{TRMIP } (w(t)) = \text{duration of training (min)} \times \Delta\text{HR ratio} \times Y$$

$$\text{Where } \Delta\text{HR ratio}=\frac{HRex - HRrest}{HRmax - HRrest}$$

Where $Y = 0.64e^{1.92x}$ for males, $Y = 0.86e^{1.67x}$ for females,

$E = 2.712$, and $x = \Delta\text{HR ratio}$

Equation 5. Calculation for training impulses.

Y is a weighting factor that emphasizes high intensity exercise and avoids disproportionate importance of the type of exercise, whether long-duration, low intensity or short duration, high intensity exercise (4). The use of training impulse (TRIMP) is limited to the need of heart rate monitors throughout training. Another limitation to using TRIMP to quantify training load is the inability to quantify non-aerobic methods of exercise like resistance training (4, 10).

2.3.6 Summated Heart Rate Zone Score

The summated heart rate zone score is a five heart rate zone modification to the calculation of training impulses that simplifies the quantification of interval training (10, 20).The time spend in five HR zones was multiplied by a corresponding weighting factor (**Table 3**) (10). The results of a study examining the variance in the relationship between objective methods like summated heart rate zone and TRMIP and subjective methods like session RPE suggested that for athletes who spent a greater percentage of their training time doing high-intensity exercise, the subjective RPE-based method accurately quantifies the athlete's workload where the objective heart rate-based equations may overestimate training load (9). On the other hand, in athletes who spent an equal amount of their training time doing low-intensity exercise, the session RPE method may overestimate training load and the heart rate-based methods may underestimate training load. The authors suggest that it may be the weighting system used in this equation that limits its accuracy (9). After an extensive review of the literature, there appears to be no evidence that the summated heart rate zone score method of quantification has been validated. The summated heart rate zone equation may therefore have been derived theoretically and not through experimentation, raising the question of the legitimacy of validating the session RPE method against this heart rate based method (10).

Table 3. Weighting factors for respective heart rate zones (20).

% HRmax	Weighting Factor
50- 60%	1
60-70%	2
70-80%	3
80-90%	4
90-100%	5

2.4 Session Rating of Perceived Exertion as a Measure of Workload

2.4.1 Defining Session Rate of Perceived Exertion

Session RPE takes Borg's RPE scale and multiplies the value by the total duration in minutes of the training session to create a single measure of internal training load in arbitrary units (73). Fullarton and Benton studied how session RPE can be used to control and monitor internal training load in national rugby league athletes. Data was collected throughout the year after every training session and game the athletes completed. Training load was calculated by multiplying session RPE x duration (minutes). Collection of RPE was completed by asking the athletes "How was your workout?" The question requires the athlete to think globally rather than specifically. Session RPE advantages include how it is minimally invasive, easy to collect, and easy to implement. Session RPE provides accurate feedback from athlete on actual internal training load and strain vs. desired training loads (**Figure 1**) (27). Session RPE may be less sophisticated compared to heart rate methods, but it may be more sensitive to internal training load than heart rate (73). It identifies individual athletes at risk for injury and athletes who find the training load too high and is useful for identifying overtraining or training induced fatigue. By collecting session RPE as a measure of workload, the staff can create training programs that tailor volume and intensity to match the athletes training load and strain threshold to optimize performance (27).

2.4.2 Validation of Session Rating of Perceived Exertion

Even with the different methods measuring internal and external workload, the need for a method that is successful in monitoring training in a variety of exercises still exists. Traditionally, Banister's training impulse concept has been the gold standard in monitoring workload. However, there are two major limitations to using the training impulse method. The first limitation is that monitoring heart rate over a long period of time can be very variable in accuracy and depend on the athletes' consistent use as well as working correctly in every session (26). Next, heart rate is a poor method of evaluating high-intensity exercise like, interval training, weight training, and plyometric training. Foster et al. developed a modification of Borg's RPE method called session RPE, which uses RPE as a marker of intensity within the training impulse method. Session RPE has been shown to correspond with heart rate and blood lactate markers of exercise intensity (26, 48, 62).

Foster et al. (26) applied session RPE to different types of exercise training to test session RPE's correlation to heart rate. The first part of the study the participants had a common exercise activity that allowed good quantitative control of the exercise performed on the cycle ergometer and treadmill. During the first part, subjects were well trained cyclists. In a maximum exertion test, VO_2peak, blood lactate, and heart rate were measured. Next, each subject underwent eight randomly ordered exercise training bouts differing in length and intensity. Heart rate, RPE, and blood lactate were all taken during the exercise bouts. Another RPE was recorded 30 minutes post-exercise for the entire session. An exercise score for each session was computed by multiplying the duration of the exercise session by the session RPE for the session. In the second part of the study, the subjects were members of a collegiate men's basketball team who were monitored during basketball practices and competitions. Heart rate was monitored, recorded, and analyzed using the summated HR method. Thirty minutes after the session, participants rated the overall difficulty of the session using session RPE (**Table 3**) (26).

Table 4. Comparison of calculated exercise training impulse scores using summated heart rate (HR) zone method and the session rate of perceived exertion (RPE) method as a prediction of performance (26).

	Summated HR zone	Session RPE
30 min steady state	110 ± 24	130 ± 57*
60 min steady state	216 ± 39	270 ± 63*
90 min steady state	350 ± 44	432 ± 67*
30 s/30 s interval	107 ± 14	131 ± 45*
60 s/60 s interval	117 ± 18	148 ± 54*
120 s/120 s interval	114 ± 17	146 ± 47*
+10% interval	114 ± 16	136 ± 60*
+25% interval	117 ± 18	148 ± 54*
+50% interval	114 ± 111	161 ± 46*
Basketball	652 ± 59	744 ± 84*

* $p < 0.05$ summated HR zone vs. session RPE.

Results showed that both the interval trained cyclists and the basketball players HR zone correlated to the session RPE. Both groups gave higher exercise scores in the RPE than the summated HR method (26). The summated HR zone is based on 5 zones, so an athlete working at maximal HR for the entire exercise session would have their exercise duration multiplied by 5 (51). In contrast, session RPE has 10 effective zones creating a high multiplier for the exercise session, especially if the intensity was high. The athletes showed consistency when reporting session RPE and the value reflecting the athlete's performance was portrayed accurately under a specific training load. The overall consistency between summated HR zone and session RPE methods of monitoring training suggests that session RPE can be useful over multiple types of exercise (26).

Present data support the use of the session RPE method as a subjective method for monitoring training load during high-intensity, non-steady state exercise like team sports. Session RPE is a simple, accurate method and is a useful technique for quantitating training load in a variety of athletic applications. Data also show that it is a reliable method that is consistent with objective physiological indicators of the intensity of the workout (26, 48, 62).

2.4.3 Timing and Session RPE

Traditionally, session RPE is recorded thirty minutes after a training session or competition. Uchida et al. (70) researched if timing of the measurement of session RPE altered the RPE rating in boxers. No significant difference was observed in session RPE load measures recorded 10 or 30 minutes after easy, moderate, and hard training sessions. Mean HR was significantly different between each intensity. The main finding of the study is there was no significant difference in RPE taken 10 minute or 30 minutes after easy, moderate, or hard session. The time observation from this study only further implies that session RPE is a valid, reliable method for monitoring training load (70).

2.5 Acute:Chronic Workload Ratio

2.5.1 Acute Workload

Acute training loads can be as short as one training session. However, in team sports, one week of training is a more common way of quantifying acute workload. Since acute training loads are usually a short period of time, they can be analogous to a state of fatigue (31). Sharp spikes in acute workload compared to chronic workload are associated with an increased risk of injury in Australian football players. Murry et. al showed pre- vs. in-season acute total distance (m) was not significantly different (P<0.069), acute low speed distance (m) was significantly different (p<0.032), acute moderate speed distance (m) was significantly different (p<0.042), high speed distance (m) was significantly different (p< 0.001), acute very high speed distance (m) was significantly different (p<0.001), and acute player load (au) was significantly different

($p<0.046$). Higher acute workload relative to chronic workload increases risk of injury in the subsequent week to the workload being performed. Players may not be able to handle sharp spikes in acute training during season compared to pre-season, most likely due to the extra physical demands of competition and the need for recovery (52).

2.5.2 Chronic Workload

Chronic training loads represents a rolling average of the most recent 3-6 weeks of training and a longer duration of training and can therefore be analogous to a state of fitness as detailed by Banister et al. fitness and fatigue model (31). When chronic workload is greater than acute workload, a lower risk of injury is observed. In Australian football players, a pre- vs. in-season chronic total distance (m) was higher than the acute distance ($p<0.024$), chronic low speed distance (m) was higher than the acute distance ($p<0.020$), chronic moderate speed distance (m) was higher than the acute distance ($p<0.006$), high speed distance (m) was higher than the acute distance ($p< 0.001$), chronic very high speed distance (m) was higher than the acute distance ($p<0.001$), and chronic player load (au) was higher than acute player load ($p<0.007$). From the results, high chronic workloads alone are associated with a lower injury risk in a group of Australian football players, suggesting that higher chronic workloads may be protective against injury (52).

Hulin et al. (36) studied elite ruby league players and reported that compared with all other rations, a very-high acute:chronic workload ratio (>2.11) demonstrated the greatest risk of injury in the current week and subsequent week. High chronic workload combined with a moderate workload ratio (1.02-1.18) had a smaller risk of injury than low chronic workload. The results showed higher workloads can have a positive or negative influence on injury risk specifically when players with a low chronic workload are compared to a high chronic workload. Players with a high chronic workload are more resistant to injury with moderate-low through moderate-high acute:chronic workload ratio (0.85-1.35) and are less resistant to injury when subjected to spikes in acute workload leading to an acute:chronic workload ratio of 1.5 or greater (36).

2.5.3 Contemporary Quantifications of Acute:Chronic Workload

Comparing the chronic workload to the acute workload as a ratio provides an index of preparedness of the athlete based on Banister et al. (4) Fitness and Fatigue Model. If the acute training load is low (fatigue is low) and chronic training load is high (fitness is high), then the athlete is prepared for competition or sustained training level. The ratio of acute:chronic ratio should be close to one or less (31). On the other hand, if the acute training load is high (fatigue is high) and chronic training load is low (fitness is low), then the athlete is not prepared and is at higher risk of injury. When the acute:chronic ratio is greater than one, the athlete is in a fatigued state (31). An acute:chronic workload ratio of 0.5 would suggest that an athlete trained or completed only half as much of the workload in the most recent weeks as what he/she had prepared for over the past 4 weeks. An acute:chronic workload ratio of 2.0 suggest that the athlete performed twice as much of the workload in the current week as what he/she had prepared for over the previous 4 weeks. “Spikes” in training and playing load are defined as periods where a player has an acute:chronic workload >1.5 (6).The use of the acute:chronic workload ratio emphasizes the negative and positive aspects of training (35).

In elite cricket fast bowlers, a study was conducted using session RPE as an internal measure and balls bowled as an external measure to quantify training load over four seasons. The relationship between acute external workloads in the current week and injury was significant ($p=0.0001$), with higher external workloads associated with a lower injury risk. No relationship was found between acute external workloads and injury in the subsequent week ($p>1.0$). The relationship between higher chronic external workloads in the current week ($p=0.002$) and subsequent week ($p=0.017$) were associated with lower injury likelihoods. For internal workloads, no relationships were found between acute or chronic internal workloads in the current or subsequent week. The size of the acute workload in relation to the chronic workload provided either a negative positive training-stress balance. A negative training-stress balance occurred when the acute workload was close or similar to the chronic workload. A negative training-stress balance was associated with an increased risk of injury in the subsequent week for the internal workload ($p=0.009$) and the external workload ($p=0.01$). (35).

2.5.4 Acute:Chronic Workload Ratio and Risk of Injury

When considering the acute:chronic workload ratio, clinicians should understand that normal training should include ratios above 1.0 when the athlete is increasing his/her training load. How far above 1.0 and for how long will be what influences injury risk within the athlete. A large number in a ratio can be from a small denominator or a by a large numerator, which would reflect a relatively large acute workload or a relatively small chronic workload. Injuries can also occur when the athlete undergoes significant loading in a single week (large numerator) or when training load has decreased over the past four weeks (small denominator) even with a normal acute workload (6).

Data collected from three different sports (cricket, Australian football, and rugby league) was interpreted and applied to the acute:chronic workload ratio in **figure 2.** Players with a high chronic workload are more resistant to injury with moderate-low through moderate-high acute:chronic workload ratio (0.85-1.35) and are less resistant to injury when subjected to spikes in acute workload. As the acute workload increases leading to an acute:chronic workload ratio of 1.5 or greater, injury risk increases (34). In terms of risk of injury, acute:chronic workload ratio in the range of 0.8-1.3 could be considered the training "sweet spot." In the "sweet spot" the acute:chronic workload ratios show low risk of injury. An acute:chronic ratio > 1.5 could be considered the "danger zone." The "danger zone" contains acute:chronic ratios where injury risk is high. To prevent injuries the athlete should be within 0.8-1.3 acute:chronic ratio. Successful sporting teams report lower injury rates and greater player availability than unsuccessful teams (6, 31).

Murray et al. (52) conducted a study on 59 elite Australian Football players over two seasons (16 weeks pre-season and 23 weeks in-season). During the study, 40 injuries were recorded, with 18 of the injuries obtained during the pre-season. The most common injury sites pre-season were the hamstring and thigh and in-season were hamstring, calf, and thigh injuries. Descriptive statistics from the study can be seen in **figure 2** below. To summarize the findings related to statistics, acute workloads were significantly higher ($p < 0.05$) during the pre-season period for low, high, and very high-speed distances, and player load when compared with the in-season period.

Similarly, chronic workloads were significantly higher ($p<0.05$) for high and very high-speed distance during the pre-season period. However, chronic workloads for total, low, and moderate speed distance were significantly higher ($p <0.05$) during the in-season period. The acute:chronic workload ratio was significantly higher ($p<0.05$) for total, low, moderate, high, and very high-speed distance along with player load during the pre-season period when compared with the in-season period (52).

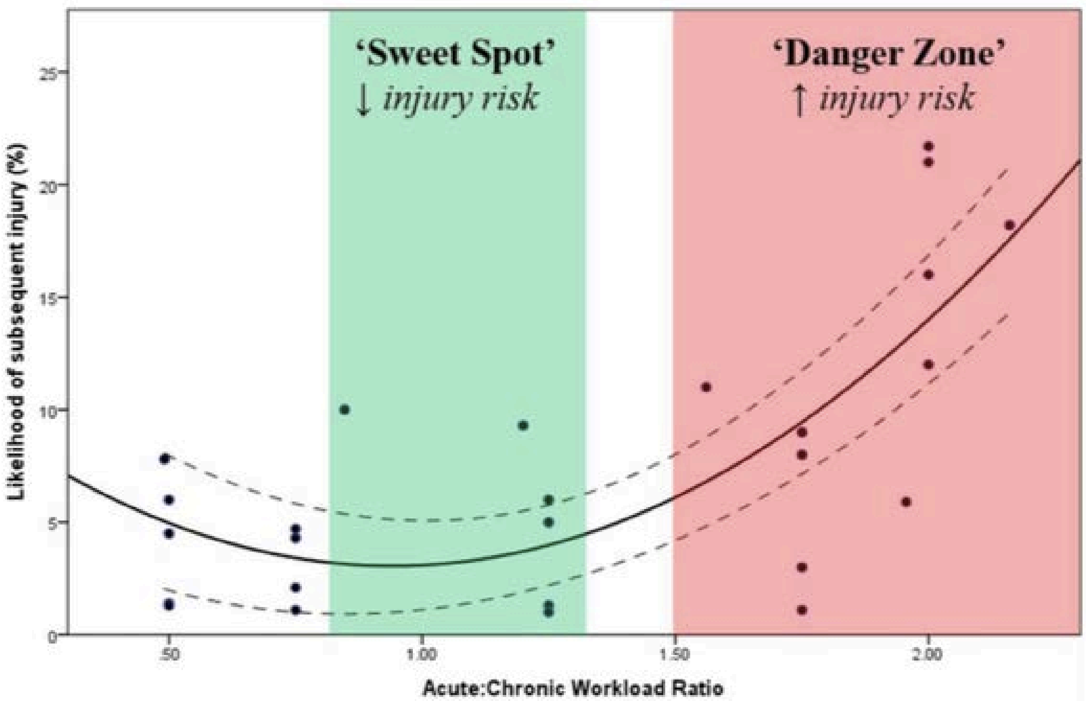

Figure 2. Guide to interpreting and applying acute:chronic workload ratio (31). Chronic workload is the rolling 3-6 weeks while the acute workload is the immediate week to a training session or competition.

In summary, chronic workload was greater than acute workload, the acute:chronic workload ratio was lower resulting in observed lower risk of injury. When there were sharp spikes in acute workload compared to chronic workload, the acute:chronic workload ratio was higher resulting in association with greater injury risk. The application of the study shows the need to increase workload systematically and progressively in order to reach high chronic workloads in both pre-season and in-season training to prevent injuries and increase performance (52).

Similarly, Hulin et al. (36) studied 53 elite rugby players over two seasons (13 weeks pre-season and 27 weeks in-season). Over the course of the study, a total of 205 injuries were recorded with the most common injury sites being the thigh, knee, and ankle. A very-high acute:chronic workload ratio in the current week of >2.11 was associated with an injury risk that was: 1) 6.9 times greater than the risk of injury in a very-low acute:chronic workload ratio of <0.30 2) injury risk was 3.4 times greater than a low acute:chronic workload ratio of 0.31-0.66 3) injury risk was 2.3 times greater than a moderate acute:chronic ratio of 1.03-1.38.

A very high two-week average acute:chronic workload ratio of >1.88 was associated with a risk of injury that was: 1) 2.2 times greater than a low acute:chronic ratio of 0.46-0.74 2) injury risk that was 1.9 times greater than a moderate-low acute:chronic ratio of 0.75-1.01 3) injury risk 2.4 times greater than a moderate acute:chronic ratio of 1.02-1.30. In the subsequent week, a very-high acute:chronic workload ration demonstrated a 10-fold increase in injury risk compared with very-low ratio. Athletes can sustain a spike in the acute:chronic workload ratio as training becomes more intense, but a double spike in the acute:chronic workload ratio is what leads to a greater risk of injury. A novel finding of this study was that a high chronic workload combined with moderate, and moderate-high workload ratios had a smaller risk of injury than a low chronic workload combined with several acute:chronic workload ratios (36).

2.6 Peak Performance

2.6.1 Performance in Sports

Performance in most sports is determined by the athlete’s technical, tactical, physiological, and psychological/social characteristics (3). In some sport disciplines, like marathon running, rowing, and 100-m run performance is closely related to the physical capacity of the athletes, whereas other sports like ball games, high tactical and technical standards may make up for weakness within the fitness level. Most sports require the athletes to have a high standard of fitness to cope with the physical demands of the competition and to allow for their technical and tactical skills to be used throughout the competition. Under optimal conditions, the demand in sports are closely related to the athlete’s physical capacity, which can be divided into categories: 1) endurance 2) the ability to exercise at high-intensity for a prolonged period 3) the ability to sprint and 4) the ability to develop a high power output (force) in single actions like kicking or jumping (3).

2.6.2 Defining Peak Performance

Peak performance is a state of superior functioning that characterizes optimal sports performances. It results in personal bests and outstanding achievements. Peak performance is a prototype of superior use of human potential, often rising above prior standards of performance more fully than could reasonably be expected. It is also describes the upper limits of functioning (56, 57). The distinguishing characteristics of peak performance are full focus and self in clear process. Self in clear process refers to the clarity of inner processes, awareness of power, and clear focus (58).

2.6.3 The Effect of Training on Overuse

Training loads determine physical performance ability, but are subject to individual variations. Overall, it is suggested that physically appropriate, higher training loads are associated with more positive performance adaptation to a certain point (32). If higher training loads surpass positive performance, an overuse injury could occur. Recently, it has been suggested that an overuse injury is a training load prescription error. Overuse injury can form the great majority of injury burdens within sports and is driven by incorrect training practice. Because overuse injuries are a concern, medical staff advocate for lower training loads. However, if low injury rates are the primary aim, training loads should be minimized and alternately physical preparation training loads should be maximized (32).

2.6.4 The Acute:Chronic Workload Ratio and Performance

Using the acute:chronic workload ratio is extremely valuable for optimizing training loads in relation to improving athletic performance and guard against overuse. For performance to be maximized and injury to be minimized, the training staff should create high chronic training loads in their athletes, well in excess of the average demands of competition (32). When improving an athlete’s performance is the main goal of the training staff, each member of the staff should focus in the pre-season period as well as during season on creating a high chronic training load, which is achieved through staged monitored increases. The athlete should also understand the importance of high chronic training loads on performance. If athletes fail to understand the relationship between periods of reduced activity and the associated reduction in chronic loading, the athletes performance will decrease and risk of injury increase compared to athletes who better understand the relation between training loads, injury, and performance (32).

2.7 Conclusion

Understanding internal and external training loads provides a greater insight to how an athlete responds to training stress. RPE has traditionally been an excellent indicator for expressing the internal response to external training loads. The acute:chronic workload ratio provides an index of preparedness of the athlete and is useful in determining injury risk in athletes. The acute:chronic load ratio is a validated method of analyzing session RPE data collected from athletes. Quantifying training load is important in determining an athlete's ability to reach peak performance. Currently, to our knowledge, there is no research on quantifying training load in elite track and field athletes. Therefore, this investigation will, for the first time, examine the acute:chronic training load ratio and its relationship to sprint performance during competition in elite division 1 NCAA track and field sprinters during the spring season of 2018.

CHAPTER 3

METHODOLOGY

3.1 Participants

Male and female (N=7; 4 male; 3 female) sprinters (100m, and 200m) on the collegiate Track and Field team were included in this retrospective analysis of the 2018 outdoor season (13 weeks, 7 meets). Participants gave written and oral consent (**APPENDIX A**) prior to the 2018 season for any regularly collected data to be used in future analysis. Participants were eligible to take part in the study if they met the following criteria: 1) student-athlete at Florida State University for the 2018 season, 2) active sprinter in the 100m or the 200m events, and 3) had access to a computer or cellular device to self-report data. Participants were excluded from the study if they meet the following criteria: 1) failed to self-report data on a consistent basis, and/or 2) did not comply to NCAA rules and regulations. This study was approved by the Florida State University's Human Subjects IRB Committee (**APPENDIX B)**.

3.2 Study Design

This was a retrospective study, analyzing session rating of perceived exertion (sRPE) and the acute:chronic workload ratio amongst division 1 NCAA collegiate track and field sprinters at Florida State University. The present study sought to identify the correlation between acute:chronic workload ratio (using sRPE) and peak performance in the 100m and 200m events.

3.2.1 Data Collection

The Florida State University strength and conditioning, sports medicine, and Institute of Sports Sciences and Medicine staff collaborated to collect self- reported data on RPE through an athlete management system (AMS; Kitman Labs, Dublin, Ireland) as part of routine data analytics on the university's track and field team. As such, the sprinters were familiarized with the AMS and the Borg CR-10 RPE Scale (**Appendix C**) prior to data collection.

Specifically, the 100m and 200m sprinters were prompted electronically (text and email alert) seven days per week, 30-60 minutes after the completion of either a training session or competition, to rate their perceived intensity of the exercise session as a whole using the modified Borg CR-10 RPE scale through the AMS. The daily training load, measured with arbitrary units (AU), was automatically quantified in the AMS by multiplying each athlete's RPE by the training duration in minutes. The sRPE was used to estimate the internal workloads.

3.2.2 Events Chosen

Sprinters that competed in the 100m and 200m sprint events were included in the analysis. In the 2018 outdoor season, the 100m and 200m sprinters had the opportunity to compete in seven competitions including Atlantic Coast Conference (ACC) Championship and the National Collegiate Athletics Association (NCAA) Championship. All seven competitions were analyzed (however, not all sprinters participated in all seven competitions).

3.2.3 Peak Performance Determination

The sprinters' race times and ranks through the duration of the 2018 outdoor season were posted to Track and Field Results Reporting System (TFRRS) (77), a universally accessible roster. The present study used the race times and individual z-scores for 100m and 200m races to quantify performance, and correlated with the acute:chronic workload ratio as measured by sRPE.

To investigate the relationship between peak performance and the acute:chronic workload ratio, we first determined each individual sprinters best performance over the seven meets. The average of the race times for each individual sprinter in each of the competitions that they participated in were set as 0.00. If a sprinter's time in a specific race is a negative score, this demonstrates that for that individual, the race time was better than their own average. If a sprinter's time in a specific race was a positive score, the race time was a worse time than their own average. To calculate Z-score, the following calculation was used: *(race time – individual's average race time)/individual's standard deviation).*

3.2.4 Acute:Chronic Workload Ratio Determination

The acute:chronic workload ratio was determined by using each sprinter's weekly average session RPE (sRPE) from the 7 days leading up to the each of the seven competition (acute load) and dividing it by the sprinter's weekly average sRPE over the previous 28 days prior to the competitions. The acute workload was embedded in the chronic workload. The weekly averages for the sRPE's were taken from the recorded sRPE's in the AMS.

3.2.5 Confounding Variable Determination

The sprinters participated in the 2018 outdoor season, leading to the influence of environmental factors on the race times for each athlete. To account for the influence that temperature, humidity, and wind could have on an athlete's race time, weather data was collected through an online weather data base for each day the sprinters ran in the 100m and 200m events. The average temperature (degrees Fahrenheit), the average humidity (%), and the average wind speed (miles per hour) were calculated for each athlete for the races they competed in over the season. The average were used for the correlation to the athlete's best 100m race time and 200m race time to determine if any of the environmental factors influenced both the predictor (acute:chronic workload ratio) and the outcome (100m and 200m best race times).

3.2.6 Statistical Analysis

The primary statistical analysis correlated the average acute:chronic workload ratios and averages for the best race times for the 100m and 200m events. First, a correlation matrix was generated using the variables: acute:chronic workload ratio, 100m best time, 200m best time, wind speed, temperature, and humidity to identify confounding variables. Once the covariates were determined, a partial correlation as performed between the acute:chronic workload ratio and the 100m and 200m best times accounting for the confounding variables. The relationship between acute:chronic workload ratio and the sprinters' best individual times for the 100m and 200m races they participated in were analyzed.

Secondarily (and violating the statistical laws of independence), the relationship between the acute:chronic workload ratio and performance (z-scores and 100m and 200m race times) for seven time points for the seven sprinters were analyzed. Using the seven time points for seven sprinters created a possible 49 rows of data linking the acute:chronic workload ratio and performance. To represent the 49 rows of data for the 100m best race times, 200m best race times, and the z-scores, “bins” were created and pooled by sex into category ranges of <0.79, 0.8 to 1.3, 1.3 to 1.5, >1.5 according to previously published research (31).

R values were used to assess the strength of correlation between the acute:chronic workload ratio and each of the factors listed above. We defined a weak correlation as R= 0.0- 0.3, a moderate correlation as R=0.5- 0.7, and a strong correlation as R=0.7- 1.0. The data from the bins will be reported as means ± standard deviation. The statistical measures will be performed using SPSS.

CHAPTER 4

RESULTS

4.1 Results

4.1.1 Descriptive Characteristics

Table 5 summarizes the descriptive characteristics of the total sprinters (N=7), female sprinters (N=3), and males (N=4) at the beginning of the 2018 outdoor track and field season.

Table 5. Participant descriptive characteristics measured at the beginning of the 2018 outdoor track and field season for the total sprinters (N=7), female sprinters (N=3), and males (N=4).

Descriptive Characteristics	Total Sprinters (N=7)	Female Sprinters (N=3)	Male Sprinters (N=4)
Age (yrs)	21.43± 1.40	20.67 ± 1.53	22 ± 1.15
Height (cm)	167.64 ± 8.16	165.95 ± 2.93^{+}	168.91 ± 11.07
Weight (kg)	67.01 ± 13.45	55.52 ± 6.31*	75.63 ± 10.20

+ p-value >0.05, * p-value <0.05 , Note: yrs, years; cm, centimeters; kg, kilograms; Data are presented as mean ± SD.

4.1.2 Confounding Variables and Pearson Correlations

Table 6 summarizes the sprinters individual average best times in the 100m and 200m races, the average temperature (degrees Fahrenheit), the average humidity (%), and the average wind speed (miles per hour). The averages were calculated from the possible seven race days each sprinter competed in.

For a variable to be considered a confounding variable, it needs to be related to both the independent variable (acute:chronic workload ratio) and the dependent variable (time). A spurious relationship between the acute:chronic workload ratio and time occurs because both of these variables are associated but are not casually related because of the presence of wind, humidity, and temperature on the race days (13). The acute workload is embedded in the chronic workload, so it is important to include any factors that can effect the sprinters perception of performance. The acute:chronic workload ratio to 100m best times (R= 0.322), 200m best times (R= 0.295), temperature (R= 0.094), humidity (R= 0.605), and wind speed (R= 0.447). The acute:chronic workload ratio (predictor) is related to humidity and to wind, but humidity is not related to the 100m (R= 0.026) or 200m times (R= -0.110) (outcomes). Wind speed was the only variable related to the 100m (R= -0.285) and 200m times (R = -0.540) such that a higher wind speed was correlated with a faster time. High wind speed was also correlated with a higher acute:chronic workload ratio. However, none of the correlations reached statistical significance.

When performing a partial correlations covarying for wind speed, a moderate positive relationship between the acute:chronic workload ratio and 100m race times (R= 0.542) was discovered. The results from the partial correlation for the 200m race times and acute:chronic workload ratio (R= 0.711) demonstrated a moderate positive relationship also. However, there was no significance between the acute:chronic workload ratio for the 100m or 200m best race times.

Table 6. Averages calculated from the possible seven race days the sprinters competed in.

Sprinter	Average Acute:Chronic Workload Ratio (sRPE)	Average 100m Best Time (s)	Average 200m Best Time (s)	Average Temperature (degrees F)	Average Humidity (%)	Average wind (mps)
Sprinter 1	1.18	10.49	21.47	76	44.2	0.7
Sprinter 2	1.48	11.19	22.91	76.7	51.3	1.11
Sprinter 3	1.53	11.81	23.45	77.8	58.8	0.95
Sprinter 4	1.77	11.27	23.30	76.6	52.2	1.34
Sprinter 5	1.34	10.23	21.62	78.3	46.8	1.08
Sprinter 6	1.56	10.61	-	76.5	67	0.45
Sprinter 7	1.62	10.04	20.16	77.8	62.8	2.18

4.1.3 Acute:Chronic Workload Ratios and Individual Race Times

Figures 3 and **4** illustrate the relationship between acute:chronic workload ratio and the sprinters' best individual times for each of the 100m and 200m races the sprinters competed in for the 2018 outdoor season. The range of races the sprinters competed in is 2-4 races for the 100m and 200m. The figures exemplify that the majority of the sprinters had their lowest race times at a lower acute:chronic workload ratio. 85% of 100m sprinters and 60% of 200m sprinters had their lowest times within the 0.8-1.3 range previously seen in research as the lowest risk of injury (30).

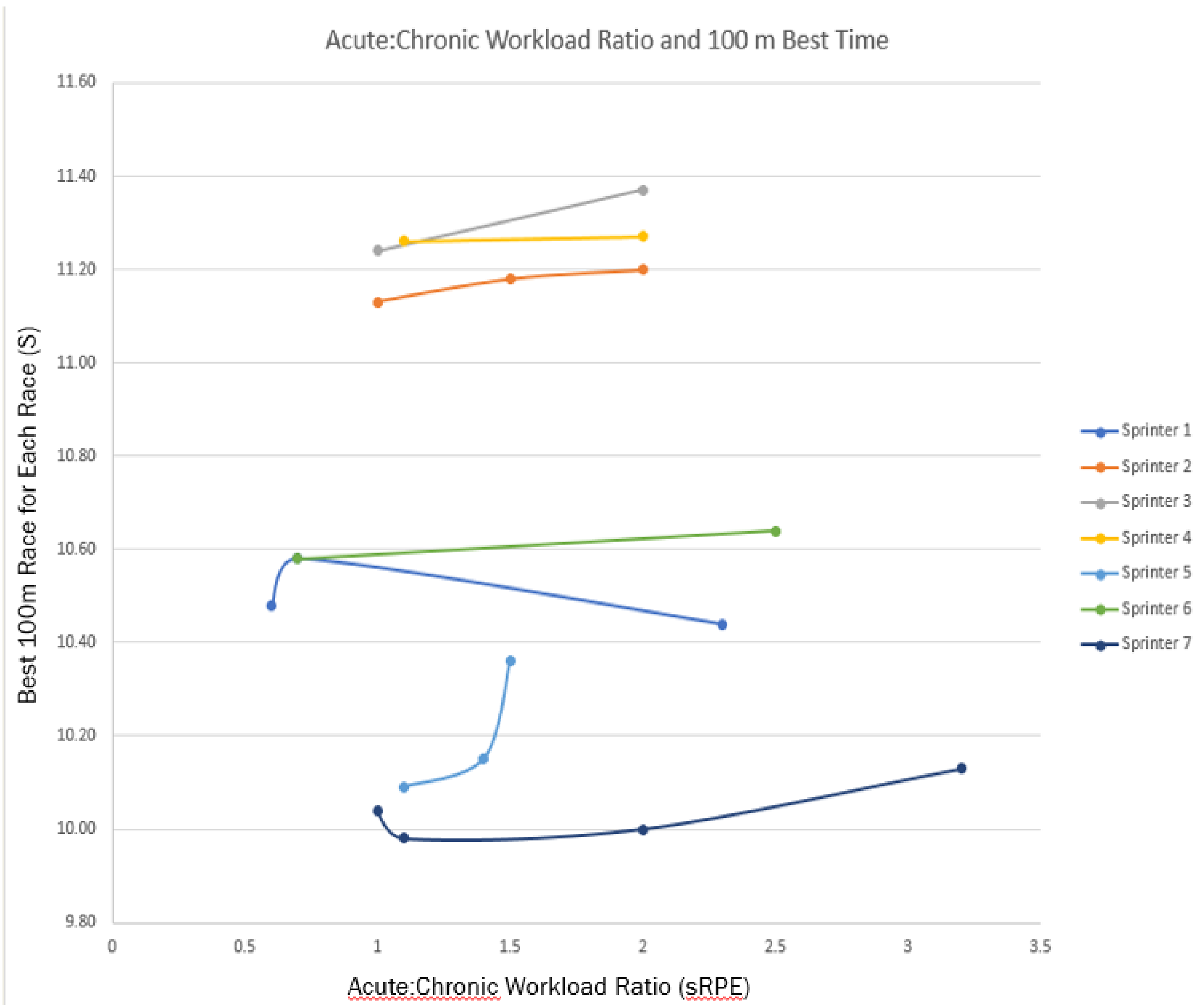

Figure 3. Relationship between acute:chronic workload ratio and the sprinters' best individual 100m times.

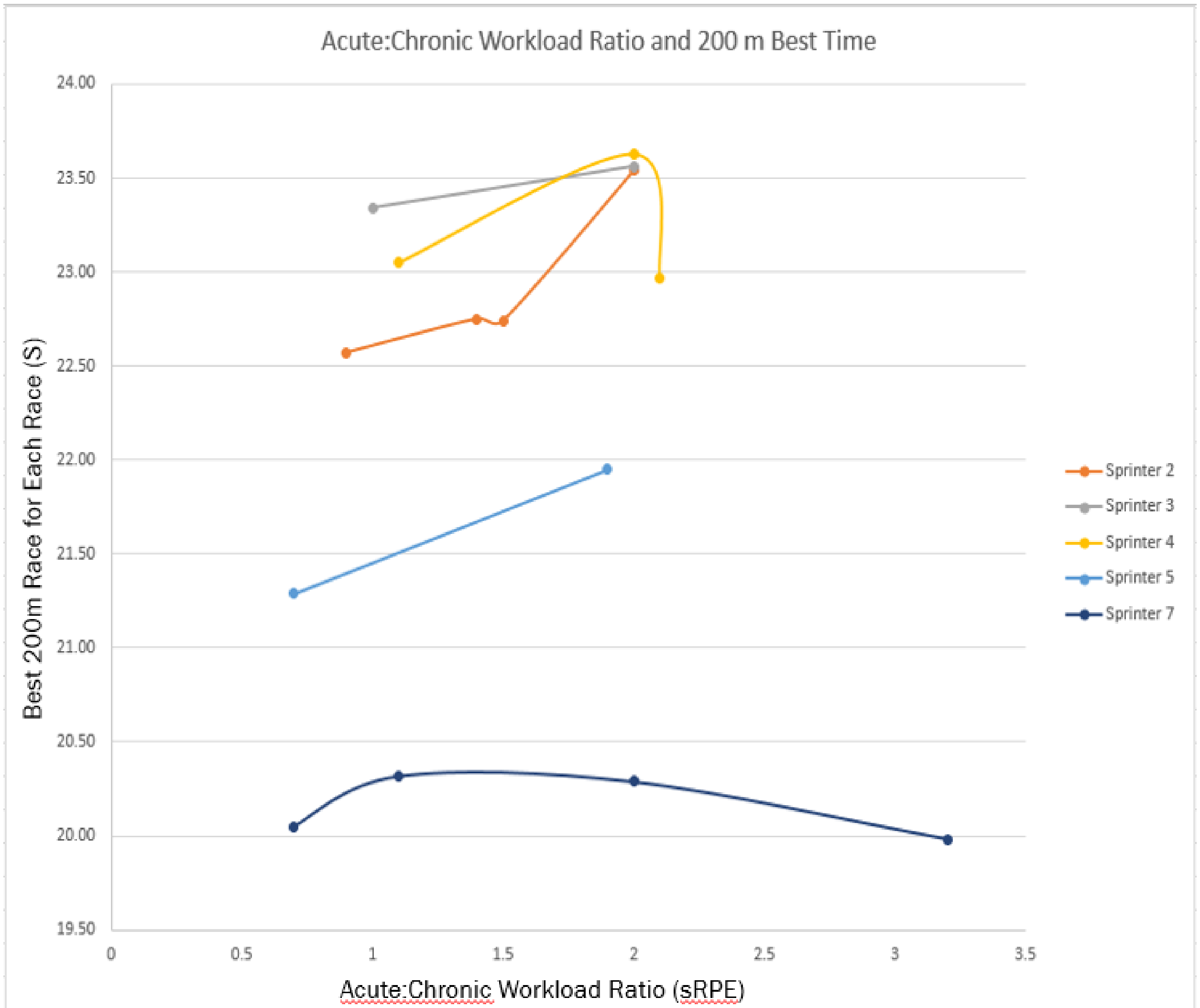

Figure 4. Relationship between acute:chronic workload ratio and the sprinters' best individual 200m times.

4.1.4 Acute:Chronic Workload Ratios and Binned Data

Examining the relationship between the acute:chronic workload ratio and performance using the time points within each of the seven individuals violated the statistical assumption of independence. To address this, the acute:chronic workload ratio and performance data for each individual was aggregated (i.e., mean of the 7 ratio scores and mean of the 7 performance scores creating 7 rows). However, when the sprinters data was represented as 49 rows, "bins" were formed to compare each person to the group. **Figures 5-8** show the binned data (<0.79, 0.8-1.3, 1.3-1.5, >1.5) for the mens' and womens'100m best times, mens' and womens'100m z-scores, mens' and women's200m best times, and mens' and women's 200m z-scores. Data are represented as mean ± SD.

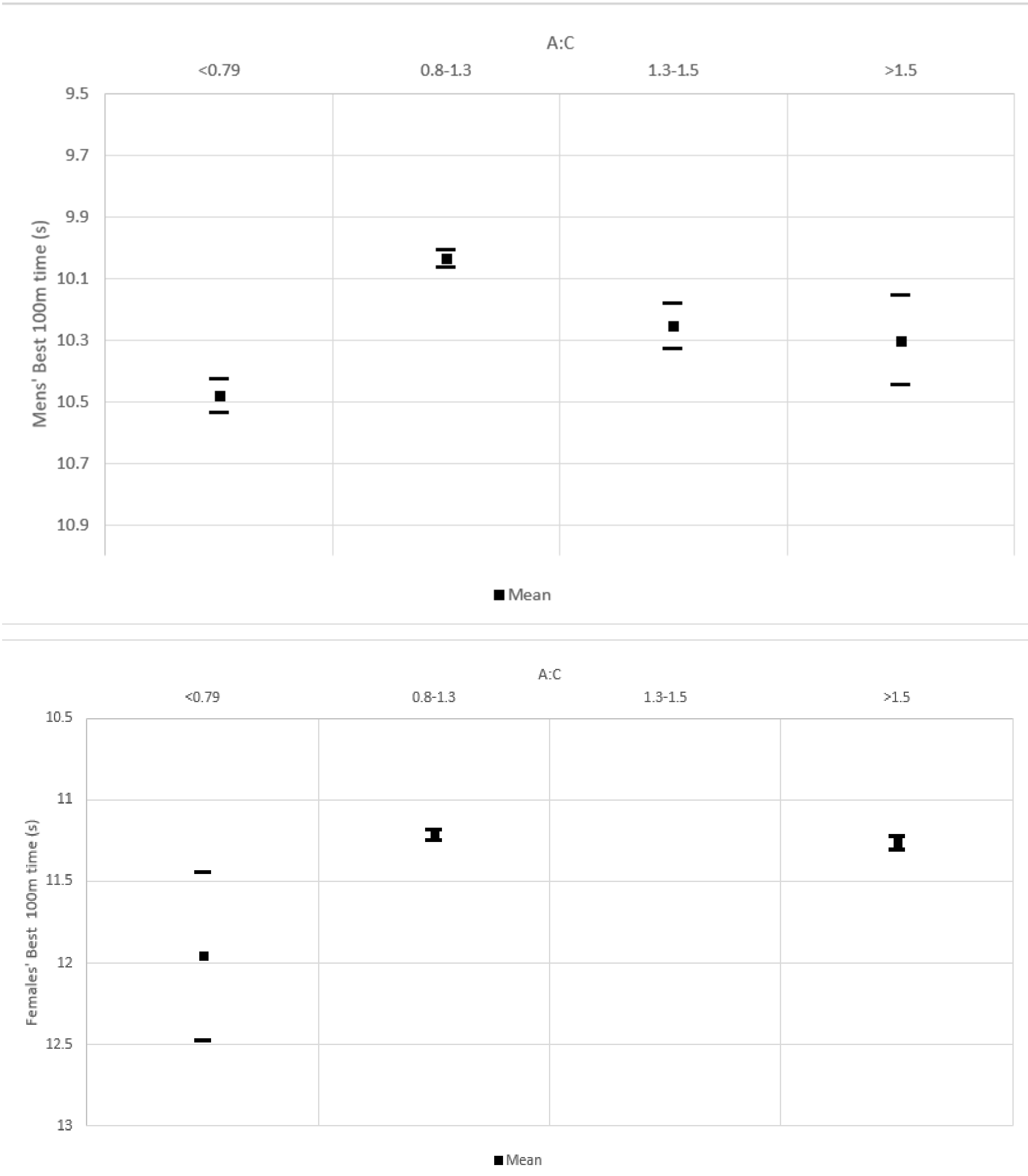

Figure 5. The acute:chronic workload ratio and the male (top pannel) and female (bottom pannel) best 100m times (seconds).

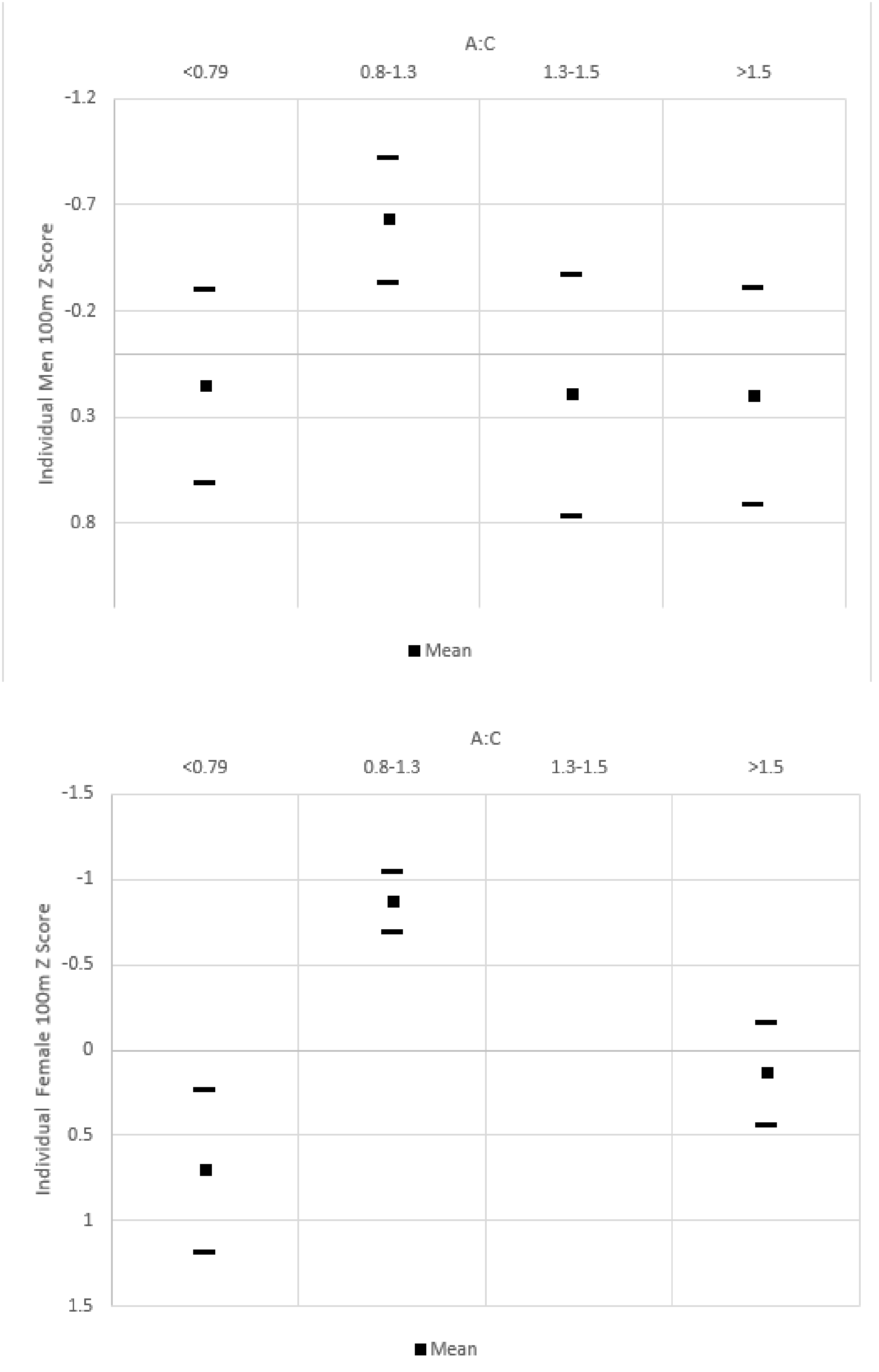

Figure 6. The acute:chronic workload ratio and male (top pannel) and female (bottom pannel) individual 100m z-score.

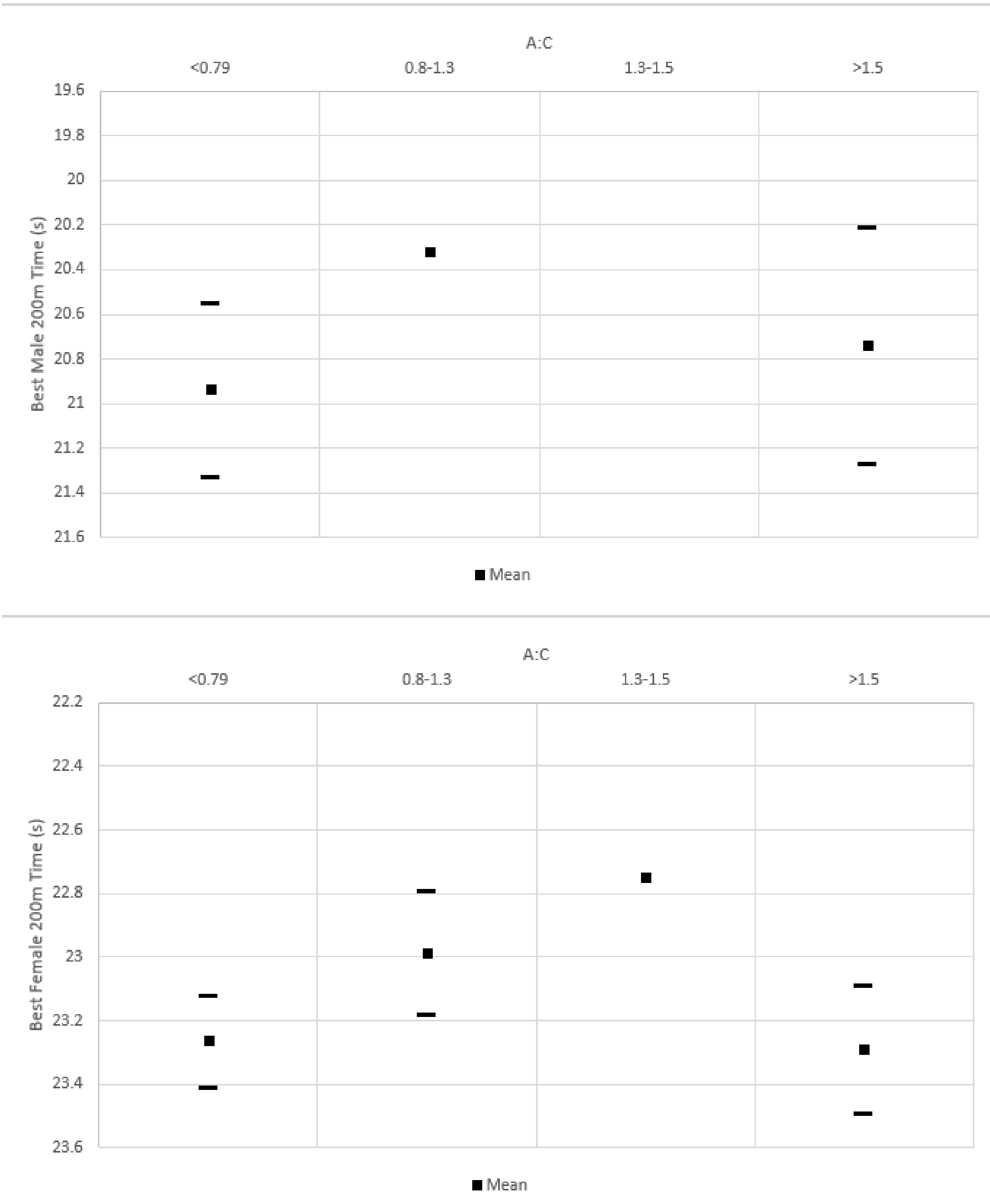

Figure 7. The acute:chronic workload ratio and the male (top pannel) and female (bottom pannel) best 200m times (seconds).

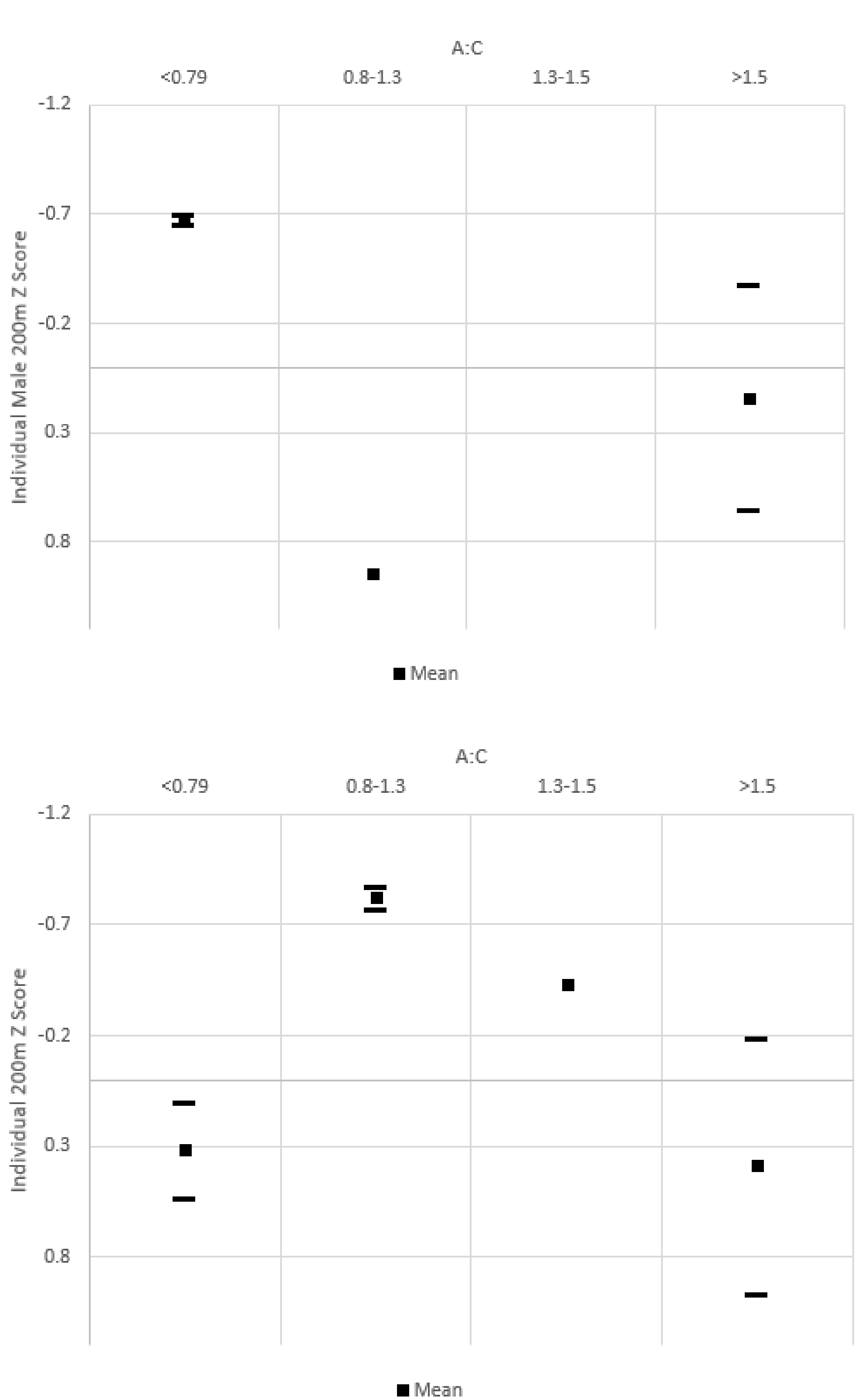

Figure 8. The acute:chronic workload ratio and the male (top pannel) and female (bottom pannel) individual 200m z-score.

CHAPTER 5

DISCUSSION

5.1 Discussion

The present study examined how the acute:chronic workload ratio influenced 100m and 200m sprinter performance. The primary findings of this investigation were: 1) a lower acute:chronic workload ratio resulted in a moderate positive correlation to lower race times, and 2) having an acute:chronic workload ratio between 0.8 and 1.3 was correlated to peak 100m and 200m sprint performance in most (85% of 100m and 60% of 200m) of the sprinters.

By examining the relationship between workload and performance, coaches and support staff may be able to make more informed choices when prescribing training loads in order to optimize training to produce peak performance in the 100m and 200m races in outdoor track and field. An athlete's workload (session RPE x session duration) completed during training sessions and competitions is referred to as training load (9, 11). Sprinters respond differently to the same training load, so the ability to measure and monitor individual training loads is important in forming training programs that will lead to peak performance (9, 11). In the current study, the response to training load was achieved by internal training load monitoring of session rating of perceived exertion (sRPE). The sprinters received a notification from the AMS 30-60 minutes after a training session or competition asking them to quantify their rating of perceived exertion (RPE) using Borg's Modified RPE Scale (**appendix C**). The strength and conditioning coach input the amount of time in minutes the athletes training session or competition was into the AMS. The sprinters' reported RPE was then multiplied by the duration in minutes of the session or competition within the AMS to provide the sRPE for each sprinter. The primary value in quantifying and recording internal training loads was to monitor the acute:chronic workloads in the sprinters using the sRPE (31). If the acute training load is low (fatigue is low) and chronic training load is high (fitness is high), then the athlete is prepared for competition or sustained training level. The ratio of acute:chronic ratio should be close to one or less (31). On the other hand, if the acute training load is high (fatigue is high) and chronic training load is low (fitness is low), then the athlete is not prepared and is at higher risk of injury. The correlations between the acute:chronic workload ratio and performance were then observed.

A novel finding of this study was that the Pearson correlations between the acute:chronic workload ratio and best race time for the 100m and 200m events were moderate and positive, indicating that the acute:chronic workload does effect performance. While the correlations for the acute:chronic workload ratio and 100m and 200m times are moderate to strong, statistical significance was not reached. The lack of significance was most likely due to the small sample size (100m N=7; 200m N=6). In competitions like the 100m and 200m races, tenths of a second can make a difference between first and second place. Even though the findings were not significant in the current study, the correlations show monitoring the acute:chronic workload ratio can provide useful information on how to best train for competitions for each individual sprinter (11, 31, 32, 52).

By observing **figures 3 and 4,** it is apparent that the lower the acute:chronic workload ratio, the lower the sprinter's time (figures 9 and 10). This preliminary data indicated that at lower acute:chronic workload ratios, most (85% of 100m; 60% of 200m) of the sprinters had their lowest race times. There are a few exceptions to the tendency, but there are many factors like chronic loss of sleep or if the sprinter was returning from an injury, that can affect the acute:chronic workload ratio (11, 28, 31, 45). In previous research, a lower acute:chronic workload ratio has been linked to a lower risk of injury (35, 36, 52). This previous research has been conducted in basketball, cricket, rugby league, and Australian football players looking for a "sweet spot" for injury where the risk of injury is lowest (6). It has been suggested that this sweet spot is an acute to chronic workload ratio of 0.8-1.49, and the current study sought to examine if the same sweet spot exists for performance (6, 11, 31). Previous research shows a positive relationships between the acute:chronic workload ratio and injury with a lower acute:chronic workload ratio being related to a lower risk of injury (34, 35, 51). The current study shows a positive relationship between the acute:chronic workload ratio and performance with a lower acute:chronic workload ratio being related to lower race times in the 100m and 200m races. However, the outliers within the data set (sprinters with an acute:chronic workload ratio of <0.8 and >1.3) we are unable to fully conclude that the same "sweet spot" for a lower injury risk is the same for a lower race time. To date, all of the research examining the acute:chronic workload ratio has been on injury.

Currently, there is no research using the acute:chronic workload ratio to predict performance and no research using the ratio in track and field sprinters. Most of the research using the acute:chronic workload ratio is in injury risk and injury prevention (11, 31, 36, 52). One study demonstrated that rugby league players who achieved a higher chronic workload possibly had improvements in physical characteristics associated with decreased injury risk (36). Other studies have shown the importance of higher fitness levels to reduce post-match neuromuscular fatigue in rugby league players (30). Additionally, Banister et al. (4, 15) originally reported acute and chronic workloads as estimates of a relative relationship between fatigue and fitness. Fatigue was expressed as the acute workload while fitness was expressed as the chronic workload. For performance to be at its optimal level, fitness (chronic) would need to be greater than fatigue (acute) (4, 15, 50, 74). When considering our findings, most (85% of100m; 60% of 200m) of the sprinters who had acute:chronic load ratios within the range of 0.8-1.3 had their peak performances showing that when fitness is greater than fatigue, performance is optimal.

Unlike previous research, we analyzed the relationship between the acute:chronic workload ratio and performance. The current study used the bins (<0.79, 0.8-1.3, 1.3-1.5, and >1.5) previous research has used for injury to see if the same sweet spot for performance exists as it does for lower injury risk (6, 11, 31). It is possible in track and field to assess performance because the sprinters' best time is their best performance. To assess the best 100m or 200m time a sprinter ran within the competitions, z-scores were formed. There is no previous research showing the use of z-scores for performance. In a sport like sprinting in track and field, hundredths of a second can make a difference between first and second place. Finding the right acute:chronic workload ratio bin for the sprinters to train during the season for their peak performance is valuable information for the coaching staff as well as the sprinters themselves.

In the current study, when all the best 100m times for the sprinters were separated by sex **(figure 5)**, a positive tendency emerged for the male and female 100m best race times such that when the acute:chronic workload was in the 0.8-1.3 bin, the lowest race times were observed. Race times for the male and female 100m best race times were higher in other bins comparatively. The variance for the data within the 0.8-1.3 bin for the males and females is low suggesting that all of the race times are close together and close to the mean. For the male z-score and the female 100m z-scores **(figure 6)**, the most negative scores for each sex were seen in the 0.8-1.3 bin meaning the 100m race times within this bin were better than the average 100m race times. The variance for the male and female data within the 0.8-1.3 bin was lowest compared to the other bins. Previous research (6, 11, 31) has showed 0.8-1.3 to be a sweet spot for decreased injury risk, and the 100m data shows it could be a sweet spot for performance as well.

The results were not as clear the male and female best 200m times **(figure 7)**, only one male sprinter ran the 200m race with a time in the 0.8-1.3 bin. However, this one race time was the lowest out of all the male 200m race time means. For the female 200m race times, the female who ran the lowest time was in the 1.3-1.5 bin. The second lowest mean for the female 200m race time was within the 0.8-1.3 bin and the variance in this bin is lower than the others. For the male z-score and the female 200m z-scores **(figure 8)**, the most negative scores for the male 200m z-score was in the <0.79 category. The most positive male 200m z-score was in the 0.8-1.3 bin meaning the time in this bin was worse than the best 200m race time. For the female 200m z-score, the most negative score with the lowest variance is found within the 0.8-1.3 bin. Within the male and female 200m binned data outliers make the results unclear.

There are several limitations to this study. The sample size of this study is low due to the use of team performance data where the sample is necessarily capped. Data were analyzed retrospectively from previously collected data from the strength and conditioning staff. We did not include other confounding variables like sleep or injury into our correlations. The direction of wind could have affected the race times; however, wind was not recorded on TFRRS, the track and field online data base for times. The data has also been collected on division 1 NCAA track and field sprinters, and therefore may not be generalized for all track athletes and collegiate divisions. More research needs to be done to clarify if acute:chronic workload ratio can be utilized to optimize performance outcomes in other sports and collegiate divisions. Future directions for research would be to have the athletes record sleep throughout the season, and to have a larger sample size.

In conclusion, this is the first investigation of peak performance relative to the acute:chronic workload in elite division 1 NCAA track and field sprinters. It was hypothesized that the sprinters who had an acute:chronic workload ratio between 0.8-1.3 the week before a competition would have improved performance in competition compared to the sprinters who had an acute:chronic workload ratio above 1.5. Our findings demonstrate that the acute:chronic workload ratio can provide a good indication of training loads to reach peak performance, as the correlations between the acute:chronic workload ratio and 100m (R= 0.542) and 200m (R= 0.711) times were moderate and positive, supporting our hypothesis. However, with the small sample size, it is not necessarily applicable to all sprinters. While more research is needed, the current study exhibits the utility of using the acute:chronic workload to monitor training load within individual athletes. Our results establish that the acute:chronic workload ratio can be a beneficial workload management tool for coaches and support staff to create a training program for the sprinters to reach peak performance.

APPENDIX A

HUMAN SUBJECT APPLICATION FOR FULL IRB

Human Subjects Application For Full IRB and Expedited Exempt Review

Print

1. Project Title and Identification

1.1 Project Title

Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Project is: Thesis

1.2 Principal Investigator (PI)

Name(Last name, First name MI): Ormsbee, Michael James	Highest Earned Degree: Doctorate
Mailing Address: 430 Sandels Building Tallahassee, FL 32306	Phone Number: 850-644-2194
	Fax:
University Department: NUTRITION FOOD AND EXERCISE SCIENCES	Email: [redacted]
The training and education completed in the protection of human subjects or human subjects records: FSU Training Module NIH (if less than 3 years old) HIPAA (additional training if this study involves HIPAA-protected information) CITI	Occupational Position: Faculty

1.3 Co-Investigators/Research Staff

Name(Last name, First name MI): Hanna, Brett ; Co-Investigator	Highest Earned Degree: Bachelor's Degree
Mailing Address: 1493	Phone Number: 850-645-1016
	Fax:
University Department: NUTRITION FOOD AND EXERCISE SCIENCES	Email: [redacted]
The training and education completed in the protection of human subjects or human subjects records: FSU Training Module HIPAA (additional training if this study involves HIPAA-protected information)	Occupational Position: Student

Name(Last name, First name MI): Saylor, Hanna ; Co-Investigator	Highest Earned Degree: Bachelor's Degree
Mailing Address: 1493	Phone Number: 850-645-1016
	Fax:
University Department: NUTRITION FOOD AND EXERCISE SCIENCES	Email: [redacted]
The training and education completed in the protection of human subjects or human subjects records: FSU Training Module HIPAA (additional training if this study involves HIPAA-protected information)	Occupational Position: Student

Name(Last name, First name MI): Schuster, Jake ; Co-Investigator	Highest Earned Degree: Master's Degree
Mailing Address: 1493	Phone Number: 561-720-3014
	Fax:
University Department: Athletics	Email: jschuster@fsu.edu
The training and education completed in the protection of human subjects or human subjects records: FSU Training Module HIPAA (additional training if this study involves HIPAA-protected information)	Occupational Position: Staff

1.4 Faculty Advisor/Department Chair/Dean Information

Name(Last name, First name MI): Ray, Chester ; Chair	Highest Earned Degree:
Mailing Address: 1493	Phone Number: 644-1850
	Fax:
University Department: NUTRITION FOOD AND EXERCISE SCIENCES	Email: [redacted]
The training and education completed in the protection of human subjects or human subjects records:	Occupational Position:

1.5 Does this project/study involve collaboration with any sites and/or personnel outside FSU?

2. Funding

2.1 Is this research funded by an internal (FSU) or external agency?

No

How will costs of research will be covered?

This study is requesting consent from athletes to use regularly collected data by the athletics staff. Thus, no costs are involved.

3. Institutional Oversight

3.1 Is this research proposal being reviewed by any other institution or peer review committee?

No

4. Conflict of Interest

Federal guidelines encourage Institutions to assure there are no conflicts of interest in research projects that could adversely affect the rights and welfare of human subjects. If this proposed research study involves a potential conflict of interest, additional information will need to be provided to the IRB. Examples of potential conflicts of interest may include: any sort of compensation, in cash or other form, for services to an individual and his or her immediate family, the value of which exceeds $10,000 in a one-year period or an equity interest which exceeds $10,000 or which exceeds a five percent ownership interest.

4.1 Do any of the Investigators or personnel listed on this research have a potential conflict of interest associated with this study?

No

5. Payment or Other Compensation for Research Subjects

5.1 Will you give subjects gifts, payments, compensation, reimbursement, services without charge or extra credit/class credit?

No

6. Protocol Description and Other Detail

6.1 Describe the objective(s) of the proposed research including purpose, research question, hypothesis, method, data analysis, research design and relevant background information etc.

This consent is designed to allow the use of de-identified, regularly collected existing information that was/is collected by the strength and conditioning, sports medicine, and sports nutrition athletics staff. This may have included a project involving, but not limited to, areas of biomechanics, biochemistry, sport nutrition, and/or sport psychology. The Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) performance research team use existing information recorded during athlete participation in regularly collected data by the strength and conditioning, sports medicine, and sports nutrition athletics staff in a larger data repository so that we can better understand how different factors influence athletic performance and well-being of among a wide range of individuals. The purpose of this study is to build a data repository that includes a range of information about athletic performance and well-being. This data repository will be used for research purposes.

6.2 Following categories will apply for the evaluation of the project:

- Review of Existing Data, Archives, or Medical Records

6.3 Survey Techniques: the only involvement of human subjects will be in the following categories:

- Research involving the collection or study of existing data, documents, records, specimens

6.4 This study will include following methods:

- Descriptive
- Longitudinal
- Qualitative
- Quantitative

6.5 Describe the tasks subjects will be asked to perform.
Upload surveys, instruments, interview questions, focus group questions etc. Describe the frequency and duration of procedures, psychological tests, educational tests, and experiments; including screening, intervention, follow-up etc. (If you intend to pilot a process before recruiting for the main study please explain.)

The FSU Athletics teams regularly participate in structured testing of anthropometric, body composition, health, and performance outcomes. This consent will allow for the use of existing data (de-identified) so that we may better understand how different factors influence athletic performance and well-being of among a wide range of individuals.

6.6 How many months do you anticipate this research study will last from the time final approval is granted?

48

7. Participant (Subject) Population

7.1 Expected number of participants

Number of male: 50 Number of female: 50
Expected number of participants: 100

7.2 Expected Age Range

- 18-65

7.3 Inclusion/Exclusion of Children in this Research

Exclusion

If this study would ***exclude*** children, NIH guidelines advise that the exclusion be justified, so that potential for benefit is not unduly denied. Indicate whether there is potential for direct benefit to subjects in this study and if so, provide justification for excluding children. Note that if inclusion of children is justified, but children are not seen in the PI's practice, the sponsor must address plans to include children in the future or at other institutions.

- No direct benefit established (exclusion of children permissible)

Provide justification for exclusion of children:

The proposed consent is to use data from FSU athletes that are over 18 years old. Therefore, children are not eligible.

7.4 Other Protected Populations to be Included in this Research

7.5 Inclusion and Exclusion of Subjects in this Research Study
Describe criteria for inclusion and exclusion of subjects in this study

Inclusion Criteria:

FSU Athlete

Exclusion Criteria:

Not an FSU athlete

7.6 Location of subjects during research activity or location of records to be accessed for research

- Florida State University

7.7 Describe the rationale for using each location checked above
Upload copies of IRB approvals or letters of cooperation from other agencies or sites, if it has been granted or the application submitted if approval has not been granted.

All athletes have these regularly collected measures taken on campus.

8. Recruitment of Participants (Subjects)

8.1 Describe the recruitment process to be used for each group of subjects
Upload a copy of any and all recruitment materials to be used e.g. advertisements, bulletin board notices, e-mails, letters, phone scripts, or URLs.

FSU Performance Staff regularly collects data on athletes. Therefore, athletes will be asked to initial and sign to use their de-identified data for future studies.

8.2 Explain who will approach potential subjects to take part in the research study and what will be done to protect individuals' privacy if required in this process

This will be completed by the FSU Performance team that includes professionals from strength and conditioning, sports medicine, and sports nutrition.

8.3 Are subjects chosen from records?

Yes

Are records "private" medical or student records? Yes

Who or what entity is the custodian of the rcords? Athletics Departent

Who gave approval for use of the records? Vanessa Fuchs, Senior Associate Athletic Director

8.4 FSU policy prohibits researchers from accepting gifts for research activities. Is the study sponsor offering any incentive connected with subject enrollment or completion of the research study (i.e. finders fees, recruitment bonus, etc.) that would be paid directly to the research staff?

No

8.5 Is the study going to be posted on the Research Studies at Florida State University recruiting website?

No

9. Risks and Benefits

9.1 The research may involve following possible risks or harms to subjects:

- Use of private records (educational or medical records)

9.2 Does the Research Involve Greater Than Minimal Risk to Human Subjects?
"Minimal Risk" means that the risks of harm anticipated in the proposed research are not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests.

Describe the nature and degree of any potential risk or harm for this study, as well as anticipated benefits. If this is a randomized controlled study and/or a study with multiple arms, please ensure you outline risks/harms/benefits for each arm.

9.3 Explain what steps will be taken to minimize risks or harms and to protect subjects' welfare. If the research will include protected populations (see question 7.4) please identify each group and answer this question for each group.

No extra testing is requested. This is only to use de-identified data from regular testing that is completed by the FSU athletics performance staff.

9.4 Describe the anticipate benefits of this research for individual subjects in each subject group. If none, state "None".

None- for those that participate. However, the data may help other athletes, coaches, strength and conditioning specialists, athletic trainers, and sport dietitians understand the impact of specific behaviors or factors on the development of optimal athletic performance and well-being.

9.5 Describe the anticipated benefits of this research for society, and explain how the benefits outweigh the risks.

The data may help other athletes, coaches, strength and conditioning specialists, athletic trainers, and sport dietitians understand the impact of specific behaviors or factors on the development of optimal athletic performance and well-being.

10. Confidentiality of Data

10.1 Will you record any direct identifiers, names, social security numbers, addresses, telephone numbers, email addresses, cookies etc.?

No

10.2 Will you retain a link between study code numbers and direct identifiers after the data collection is complete?

No

10.3 Will you provide the link or identifier to anyone outside the research team?

No

10.4 Where, how long, and in what format (such as paper, digital or electronic media, video, audio, or photographic) will data be kept? In addition, describe what security provisions will be taken to protect this data (password protection, encryption, etc.)

All data is stored by the FSU Athletics Performance Team staff according to all University and National guidelines. We propose to use de-identified data so that no names are ever associated with data used. The de-identified data will be kept in the PI's office (Dr. Ormsbee) and secured via lock and key and password protection.

10.5 Will you place a copy of the consent form or other research study information in the subjects' record such as medical, personal or educational record?

No

10.6 If the data collected contains information about illegal behavior, please refer to the NIH Certificates of Confidentiality Kiosk for information about obtaining a Federal Certificate of Confidentiality.

10.7 Will you be given or have access to personal information regarding employee, customer, student, parent and/or patient accounts with Florida State University?

No

11. Use of Protected Health Information (PHI): HIPAA Requirements

In the course of conducting research, researchers may desire to obtain, create, use, and/or disclose individually identifiable health information. Under the HIPAA Privacy Rule, covered entities (healthcare providers, health plans, employer or healthcare clearinghouses) are permitted to use and disclose protected health information for research with individual authorization, or without individual authorization under limited circumstances set forth in the Privacy Rule.

11.1 As part of this study, will you be accessing PHI from a covered entity for research purposes?

No

12. Informed Consent Process

12.1 Recognizing that consent itself is a process of communication, please expand on your responses to questions 8.1 and 8.2 and describe what will be said to the subjects to introduce the research.

You are participating in a project with one of the members of the Florida State University Athletics Department and the Institute of Sports Sciences and Medicine (FSUA-ISSM). This may have included a project involving, but not limited to, areas of biomechanics, biochemistry, sport nutrition, and/or sport psychology. The FSUA-ISSM performance research team would like to save the information recorded during your participation in regularly collected data by your athletics staff in a larger data repository so that we can better understand how different factors influence athletic performance and well-being of among a wide range of individuals. The purpose of this study is to build a data repository that includes a range of information about athletic performance and well-being. This data repository will be used for research purposes.

12.2 In relation to the actual data gathering, when will consent be discussed and documentation obtained? (e.g., mailing out materials, delivery of consent form, meetings)

This will be completed in-person by the FSU Athletics Performance Staff members (Strength and Conditioning, Sports Medicine, & Sports Nutrition) prior to the use of any de-identified data.

12.3 Please name the specific individuals who will obtain informed consent and include their job title/credentials and a brief description of your plans to train these individuals to obtain informed consent and answer subject's questions:

Jake Schuster - Strength and Conditioning Coach, MS trained, with PhD underway. Jake has experience with consent and more training will be reviewed with PI (Ormsbee). In addition, Robin Gibson (Head of Sports Medicine) and Kayli Hrdlicka (Head of Sports Nutrition) will be completing these regularly performed tests. Therefore, all of us will meet to go over and understand the process with obtaining consent to use the de-identified regularly collected data.

12.4 What questions will you ask to assess the subjects' understanding of the risks and benefits of participation?

Do you have any questions about the procedures or aims of this study? Do you think that you will be able to fully adhere to the process of this study? What other concerns or questions do you have before consenting to this study?

12.5 Informed Consent Waivers

☐ Request waiver of documentation of consent.

- ☐ The only record linking the subject and the research would be the consent form and the principle risk of the research would be the potential harm from a breach of confidentiality (If Checked, explain below):
- ☐ The research involves minimal risk and includes no procedures for which written consent is normally required outside the research context.

☐ Request waiver of some or all elements of consent.

- ☐ The research involves no more than minimal risk to the subjects.
- ☐ A waiver will not adversely affect the rights and welfare of the subjects.
- ☐ The research could not practicably be carried out without waiver or alteration.
- ☐ Where appropriate, the subjects will be provided with additional pertinent information after participation (If checked, explain below):

APPENDIX B

INFORMED CONSENT

FLORIDA STATE UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

Introduction

We invite you to take part in a research study at Florida State University.

Before you decide to take part, please take as much time as you need to ask any questions and discuss this study with anyone on the FSU research team, or with family, friends or your personal physician or other professional.

Key information about the research study
Things you should know:

> The purpose of the study is to build a data repository that includes a range of information about athletic performance and well-being. This data repository will be used for research purposes. If you choose to participate, you will be asked to complete the types of assessments (outlined below) that are routinely completed by the Florida State University Athletics Strength and Conditioning, Sports Medicine, and Sports Nutrition Staff.
>
> Risks or discomforts from this research include that there may be a breach of the data repository and, your data may not stay confidential. If there is a breach, then it is possible that your data might be shared with others in society such as other teams or the press.
>
> The study will not directly provide you with any additional information. However, the data may help other athletes, coaches, strength and conditioning specialists, athletic trainers, and sport dietitians understand the impact of specific behaviors or factors on the development of optimal athletic performance and well-being.

Taking part in this research project is voluntary. You don’t have to participate and you can stop at any time.

FLORIDA STATE
UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

Please take time to read this entire form and ask questions before deciding whether to take part in this research project.

Why is this study being done?

This study is being conducted by the members of the Florida State University Athletics Department and the Institute of Sports Sciences and Medicine (FSUA-ISSM). There is no outside funding involved.

The purpose of the study is to build a data repository that includes a range of information about athletic performance and well-being. This data repository will be used for research purposes. This may have included a project involving, but not limited to, areas of biomechanics, biochemistry, sport nutrition, and/or sport psychology. The FSUA-ISSM performance research team would like to save the information recorded during your participation in regularly collected data by your athletics staff in a larger data repository, so that we can better understand how different factors influence athletic performance and well-being of among a wide range of individuals.

Why are you being asked to take part in this study?

You are a member of a collegiate National Collegiate Athletic Association (NCAA) sports team at Florida State University.

FLORIDA STATE UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

How many people are expected to take part in this study?

It is expected that all members of each collegiate NCAA sports team at Florida State University will take part in this study.

Before you begin the study

You will participate in a project with FSUA-ISSM staff or equipment. Additional inclusion criteria are determined by research parameters (anthropometrics, age, gender, skill level) and specific to each proposed project or investigation.

Study procedures

If you agree and are eligible to participate in this study, we would ask you to do the following:

You will participate in a project involving one or more areas within FSUA-ISSM including biomechanics, biochemistry, sport nutrition, sports medicine, nutrition, exercise physiology and/or sport psychology. We are seeking your permission to save the information recorded from the study identified into the FSUA-ISSM data repository.

We have outlined information on the types of assessments that are routinely completed by the Florida State University Athletics Strength and Conditioning, Sports Medicine, and Sports Nutrition Staff in the sections that follow. Here we highlight the type of information collected by FSUA-ISSM for on this data repository. Please place your initials on the line indicated if you would like to give us permission to confidentially save that portion of your information into FSUA-ISSM's data repository:

FLORIDA STATE
UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

a) Subjective Monitoring: Wellness questionnaires and ratings of perceived exertion are measured via various technology involving surveys of the athlete.

b) Three-Dimensional Motion Analysis: The movements of your arms, legs, and trunk are tracked using small reflective markers that are taped on your skin. A special camera system records the movement of the markers and this information can then be used to re-create your movement patterns while you stand quietly and while you perform athletic activities (such as running). No recognizable image of your face or body is created. Instead, only a stick figure or skeleton is created.

c) Two-Dimensional Motion Analysis: A digital camera system records your movements as you perform your athletic activity. These images are recorded so that we can make sure that the testing procedures proceeded as planned. We might need these images because sometimes markers fall off or you can inadvertently step in the wrong place. Your face may appear on the video; thus, you could be identified from the images. However, we will only use these images to assess the data. We will not publish them or use them for any marketing purposes or presentations.

d) Force Plate Analysis: Special scales, embedded in the floor, measure the forces your body generates while standing on the scales and while performing your athletic activity.

e) GPS Movement Tracking, Accelerometer, and Actigraph: A small device

(approximately 1” by 2” by 1/2”) is worn in a harness under your shirt, or a bracelet-like actigraph device to wear around your wrist. The devices use accelerometer sensors and/or GPS technology to track your movement patterns during your athletic and/or normal everyday activities.

f) Muscle Activation Patterns (Electromyography): Special electromyography (EMG) and accelerometer sensors about the size of a pen cap, taped on your skin over select muscles, record how hard your muscles work while you contract them forcefully, lie down or sit at rest, and perform your athletic activity. The sensors record the electrical signal that your muscle produces and can also record how rapidly you move your limb.

g) Metabolic Testing: A metabolic instrument measures the amount of oxygen you use and carbon dioxide you breathe out at rest and during your athletic activity. While lying down, a see-through, plastic hood is placed over your head, which is connected to a hose and the metabolic instrument. The amounts of gases breathed in and out are used to estimate the amount of calories you burn at rest. During exercise, a rubber face mask is connected to a hose, which is then connected to the metabolic instrument.

h) Cardiovascular Monitoring: A small sensor (roughly 1” x 2” x 1/4”) is strapped to your chest and records the frequency of your heart beat at rest and during your athletic activity. Alternatively, small electrode pads are affixed to the skin on various areas of your body including your chest. The electrodes connect to an ECG machine that monitors the electrical activity of your heart at rest and during your athletic activity.

i) Dual-Energy X-Ray Absorptiometry: You lie face-up on a padded scanning bed for 5-10 minutes. During this time, a mechanical arm moves horizontally over your body while the machine emits low amounts of radiation in the form of x-rays. The machine accurately estimates the quantity of body tissues, including fat, muscle, and bone density. An unidentifiable image of your body (much like an x-ray image) is created. No recognizable image of your face or body is created.

j) Bod Pod (air displacement plethysmography): You will sit in a small chamber with a window for approximately 5 minutes. During this time, air is displaced around your body and your body density is measured. The machine accurately estimates the body composition. No recognizable image of your face or body is created.

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

k) Ultrasound Measurements: Non-invasive measurements of muscles, tendons and ligaments via ultrasound. Laying on a table, practitioner applies a non-stick gel to skin surface and applies ultrasound unit to the desired area to exam muscle thickness, pennation angle, or fascicle length.

l) Food Records: you will fill out routine food analysis forms with your Director of Sports Nutrition. This may include the type, amount, and frequency of foods and drinks.

m) Strength and Speed Assessment: You perform a standardized exercise task while an exercise machine or an examiner measures your strength or speed. Examples would be performing knee extensions in a seated position at a specific speed against the resistance of a device called the Humac Norm, Nordbord, or performing a 10-meter timed sprint.

n) Motion Capture System: You perform an exercise task commonly performed during training and conditioning sessions. These exercises involve a barbell and include common movements such as squats, the bench press, and bicep curls. During these exercises, the EliteForm system uses special camera technology to track the velocity of bar movement and your power output.

o) Anaerobic Cycle Ergometer: You perform a warm-up followed by a short, maximal effort exercise task on a stationary cycle to assess your anaerobic capacity. The height of the seat is adjusted to optimize your comfort. A constant, standardized amount of resistance is applied to the cycle flywheel and you cycle maximally for a specific duration (anywhere from 5 seconds to 1 minute).

p) Biochemical Assessment: Blood or saliva testing involves laboratory analysis of saliva to identify markers of the endocrine, inflammatory, immune response, and other types of conditions. Collection of blood serum or saliva is minimally invasive, requiring

1 to 5 drops of blood or approximately 2 milliliters of saliva. All Universal Precautions are observed in collection and handling of each sample prior to and during analysis.

How long will I be in this study?

You will be in this study as long as you remain an eligible member of a collegiate NCAA sports team at Florida State University.

Risks of study participation

The study has the following risks: There are minimal risks associated with participating in this study. The biggest risk is that there may be a breach of the data repository and that, as a result, your data may not stay confidential. If there is a breach, then it is possible that your data might be shared with others in society such as other teams or the press.

Because this is a research study, there may be additional risks that we cannot identify at this time.

Benefits of study participation

The benefits to study participation are: You participated in a study with FSUA-ISSM staff. Your willingness to allow us to use the information recorded during that session for our larger data repository will not directly provide you with any additional information. However, the data may help other athletes, coaches, strength and conditioning specialists, athletic trainers, and sport dietitians understand the impact of specific behaviors or factors on the development of optimal athletic performance and well-being. In addition, if you would like to learn more about the findings from any published studies emerging from the data repository, please contact the Investigators at the phone numbers listed at the end of this document.

FLORIDA STATE UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

Alternatives to study participation

The alternative is to not participate in the study.

Ending the study

If you choose to withdraw from the study, or have any questions concerning this research and your data or your participation, before or after your consent, contact the investigators or referred to a knowledgeable source. You may contact Dr. Michael Ormsbee at (850)

644-2194 (mormsbee@fsu.edu) for answers to your questions about this research study or your rights. If you are no longer an eligible member of an NCAA sports team at Florida State University, your data will no longer continue to be collected.

Study costs/compensation

Compensation: You will receive nothing of monetary value for your involvement.

Research related injury

In case of an injury, or if I have questions about my rights as a participant in this research, or I feel I have been placed at risk, I can contact the chair of the Human Subjects Committee, Institutional Review Board, through the office of the Vice President of Research at (850) 644-8633 (humansubjects@magnet.fsu.edu).

FSU Human Subjects Committee approved on 02/05/2019, void after 02/04/2020. HSC #2018.26525

FLORIDA STATE UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

Who can profit from study results?

No financial conflicts or gains have been identified in connection with this study.

Florida State University reviews staff researchers for conflicts of interest.

How Will My Samples and Data be Used?

1. The data repository will be used for future research purposes to help other athletes, coaches, strength and conditioning specialists, athletic trainers, and sport dietitians understand the impact of specific behaviors or factors on the development of optimal athletic performance and well-being.

2. If you choose to include your data within the repository, we may use your data in articles published in scientific journals or presented at scientific meetings. We would not use your name or any photo/video images of you within these publications or presentations.

Incidental and Secondary Findings

Additional studies may arise within FSUA-ISSM. If you are interested in learning about these future studies, you can choose to give our research team permission to save your contact information in a secure file and try to contact you in the future.

Confidentiality

FLORIDA STATE UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

All data collected for the purposes of this study will be treated confidentially to the extent allowed by law, unless you give us permission to use it in an alternative manner. Upon gathering data, each participant will be given an alphanumeric ID. A list linking the names and alphanumeric IDs will be stored in a password protected, secure server, only accessible to the FSUA-ISSM research staff. This list will be kept for the life of the repository. In addition, all data gathered will be transferred to secure servers in the Principal Investigator's laboratory (Dr. Michael Ormsbee). Co-investigators may include staff from athletics (strength and conditioning staff, sports medicine staff, Sports Nutrition Staff, and athletics administrators, as needed) and students from the ISSM. The current students involved include Brett Hanna, Hannah Saylor, Brandon Willingham, and Shiloah Fuller as graduate student co-investigators.

Will my medical/health information be kept private?

Your protected health information (PHI) created or received for the purposes of this study is protected under the federal regulations known as HIPAA. Refer to the HIPAA authorization for details concerning the use of this information.

We will do our best to be sure that the personal health information you provide for this study will be kept private. However, we cannot guarantee total privacy. Organizations that may look at and/or copy your records for research, quality assurance and data analysis include:

Certain government agencies (FDA, OHRP)
The FSU Institutional Review Board

What will happen to the information collected about me after the study is over?

FLORIDA STATE UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

We may share your research data with other investigators without asking for your consent again, but it will not contain information that could directly identify you. If you choose to include your data within the repository, we may use your data in articles published in scientific journals or presented at scientific meetings. We would not use your name or any photo/video images of you within these publications or presentations.

The results of this study could be published in an article or presentation, but would not include any information that would let others know who you are without your permission.

Voluntary Nature of the Study

Participation in this study is voluntary. Your decision whether or not to participate in this study will not affect your current or future relations with the Florida State University. If you decide to participate, you are free to withdraw at any time without affecting those relationships.

Contacts and Questions for the study team about the research

The researchers conducting this study associated with the Principal Investigator's laboratory (Dr. Michael Ormsbee). Co-investigators may include staff from athletics and students from the ISSM. The current students involved include Brett Hanna, Hannah Saylor, Brandon Willingham, and Shiloah Fuller as graduate student co-investigators. You may ask any questions you have now, or if you have questions later, you are encouraged to contact Dr. Michael Ormsbee at (850) 644-2194 (mormsbee@fsu.edu).

Contact information for questions about your rights as a research participant

If you have any questions or concerns about your rights as a research participant, or regarding the study and would like to talk to someone other than the researcher(s), you

FLORIDA STATE UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

are encouraged to contact the FSU IRB at telephone number 850-644-7900. You may also contact this office by email at humansubjects@fsu.edu, or by writing or in person at 2010 Levy Street, Research Building B, Suite 276, FSU Human Subjects Committee, Tallahassee, FL 32306-2742.

You will be given a copy of this form for your records.

Statement of Consent

The nature, demands, benefits and risks of the study have been explained to me. I knowingly assume any risk involved.

I have read the above informed consent form. I understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of the benefits to which I may otherwise be entitled. In signing this consent form, I am not waiving my legal claims, rights or remedies. A copy of this consent form will be given to me.

____________________ ____________

Signature of Subject Date

____

Printed Name of Subject

____

Date

____________________ ____________

Person Obtaining Consent Date

FSU Human Subjects Committee approved on 02/05/2019, void after 02/04/2020. HSC #2018.26525

FLORIDA STATE
UNIVERSITY

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Study Title: Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

Principal Investigator: Dr. Michael Ormsbee

FSU Human Subjects Committee approved on 02/05/2019, void after 02/04/2020. HSC #2018.26525

APPENDIX C

IRB APPROVAL LETTER

Office of the Vice President for Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date:02/05/2019

To: Michael Ormsbee <mormsbee@fsu.edu>

Address: 430 Sandels Building Tallahassee, FL 32306

Dept.: NUTRITION FOOD AND EXERCISE SCIENCES

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research

Florida State University Athletics-Institute of Sports Sciences and Medicine (FSUA-ISSM) Integrated Data Repository Consent.

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects

Committee. Your project is determined to be Expedited per 45 CFR § 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 02/04/2020 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is IRB00000446.

Cc:
HSC No. 2018.26525

APPENDIX D

BORG'S MODIFIED RPE SCALE

0	Nothing at all	(Just noticeable)
0.5	Very, very weak	
1	Very weak	
2	Weak	(Light)
3	Moderate	
4	Somewhat strong	
5	Strong	(Heavy)
6		
7	Very Strong	
8		
9		
10	Very, very strong	(Almost max)

- Maximal

REFERENCES

1. **A U**, **W K**. Diagnosis of Overtraining: What Tools Do We Have? *Sport Med* 32: 95–102, 2002.

2. **Akubat I**, **Barrett S**, **Abt G**. Integrating the internal and external training load in soccer. *Int. J. Sports Physiol. Perform.* (2013). doi: 10.1123/ijspp.2012-0347.

3. **Bangsbo J**. Performance in sports - With specific emphasis on the effect of intensified training. *Scand. J. Med. Sci. Sport.* 25: 88–99, 2015.

4. **Banister EW**, **JD M**, **Wenger H et al.** Modeling Elite Athletic Performance: Physiological Testing of the High-Performance Athlete.

5. **Blair SN**, **Gibbons LW**. Guidelines for exercise testing and prescription, third edition. *J Cardiopulm Rehabil* 6, 1986.

6. **Blanch P**, **Gabbett TJ**. Has the athlete trained enough to return to play safely? The acute:chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. *Br J Sports Med* 50: 471–475, 2016.

7. **Borg GAV**. Psychophysical Bases of Perceived Exertion. *Med Sci Sports Exerc* 14: 377–381, 1982.

8. **Borresen J**, **Lambert MI**. Validity of Self-Reported Training Duration. *Int J Sport Sci Coach* 1: 353–359, 2006.

9. **Borresen J**, **Lambert MI**. Quantifying training load: A comparison of subjective and objective methods. *Int J Sports Physiol Perform* 3: 16–30, 2008.

10. **Borresen J**, **Lambert MI**. The Quantification of Training Load , the Training Response and the Effect on Performance. *Sport Med* 39: 779–795, 2009.

11. **Bourdon PC**, **Cardinale M**, **Murray A**, **Gastin P**, **Kellmann M**, **Varley MC**, **Gabbett TJ**, **Coutts AJ**, **Burgess DJ**, **Gregson W**, **Cable NT**. Monitoring Athlete Training Loads : Consensus Statement. *Int J Sport Physiol Perfornace* 12: 161–170, 2017.

12. **Buchheit M**, **Racinais S**, **Bilsborough JC**, **Bourdon PC**, **Voss SC**, **Hocking J**, **Cordy J**, **Mendez-Villanueva A**, **Coutts AJ**. Monitoring fitness, fatigue and running performance during a pre-season training camp in elite football players. *J Sci Med Sport* 16: 550–555, 2013.

13. **Burns WC**. *Spurious Correlations*. 1997.

14. **Busso T**, **Carasso C**, **Lacour JR**. Adequacy of a systems structure in the modeling of training effects on performance. *J Appl Physiol* 71: 2044–2049, 1991.

15. **Calvert TW**, **Banister EW**, **Savage M V**, **Bach TIM**. A Systems Model of the Effects of Training on Physical Performance. : 94–102, 1976.

16. **Carroll TJ**, **Riek S**, **Carson RG**. Neural Adaptations to Resistance Training. *Sport Med* 31: 829–840, 2001.

17. **Coyle EF**. Physical activity as a metabolic stressor. *Am J Clin Nutr* 72: 512S–20S, 2000.
18. **Dettmers C**, **Ridding MC**, **Stephan KM**, **Lemon RN**, **Rothwell JC**, **Frackowiak RSJ**. Comparison of regional cerebral blood flow with transcranial magnetic stimulation at different forces [Online]. *J Appl Physiol* 81: 596–603, 1996. http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L26303208%5Cnhttp://pm6mt7vg3j.search.serialssolutions.com?sid=EMBASE&issn=87507587&id=doi:&atitle=Comparison+of+regional+cerebral+blood+flow+with+transcranial+magnetic+stimulation+a.

19. **Dlugosz EM**, **Chappell MA**, **Meek TH**, **Szafranska PA**, **Zub K**, **Konarzewski M**, **Jones JH**, **Bicudo JEPW**, **Nespolo RF**, **Careau V**, **Garland T**. Phylogenetic analysis of mammalian maximal oxygen consumption during exercise. *J Exp Biol* 216: 4712–21, 2013.

20. **Edwards S**. *The Heart Rate Monitor Book*. New York: Polar Electro Oy, 1993.

21. **Ferretti G**. Energetics of muscular exercise. 2015.

22. **Ferretti G**, **Fagoni N**, **Taboni A**, **Bruseghini P**, **Vinetti G**. The physiology of submaximal exercise: The steady state concept. *Respir. Physiol. Neurobiol.* 246: 76–85, 2017.

23. **Filaire E**, **Lac G**, **Pequignot J-M**. Biological, Hormonal, and Psychological Parameters in Professional Soccer Players Throughout a Competitive Season. *Percept Mot Skills* 97: 1061–1072, 2003.

24. **Foster C**. Monitoring training in athletes with reference to overtraining syndrome. In: *Medicine and Science in Sports and Exercise*. 1998, p. 1164–1168.

25. **Foster C**, **Daines E**, **Hector L**, **Snyder AC**, **Welsh R**. Athletic performance in relation to training load. *Wis Med J* 95: 370–374, 1996.

26. **Foster C**, **Florhaug JA**, **Franklin J**, **Gottschall L**, **Hrov LA**, **Suzanne P**, **Doleshal A**, **Dodge C**. A New Approach to Monitoring Exercise Training. *J Strength Cond Res* 15: 109–115, 2001.

27. **Fullarton C**, **Benton D**. Use of the Session-RPE Method for Determining Training Load in NRL Players. *J Aust Strength Cond* 23: 6–13, 2015.

28. **Gabbett TJ**. Influence of training and match intensity on injuries in rugby league. *J*

Sports Sci 22: 409–417, 2004.

29. **Gabbett TJ**. Reductions in pre-season training loads reduce training injury rates in rugby league players. *Br J Sports Med* 38: 743–749, 2004.

30. **Gabbett TJ**. The development and application of an injury prediction model for noncontact, soft-tissue injuries in elite collision sport athletes. *J. Strength Cond. Res.* (2010). doi: 10.1519/JSC.0b013e3181f19da4.

31. **Gabbett TJ**. The training — injury prevention paradox : should athletes be training smarter and harder ? *Br J Sports Med* Online Fir: 1–9, 2016.

32. **Gabbett TJ**, **Whiteley R**. Two training-load paradoxes: Can we work harder and smarter, can physical preparation and medical be teammates? *Int. J. Sports Physiol. Perform.* 12: 50–54, 2017.

33. **Giordano N**. *College Physics: Reasoning and Relationships*. Cengage Learning, 2009.

34. **Hopkins WG**. Quantification of Training in Competitive Sports: Methods and Applications. *Sport. Med.* 12: 161–183, 1991.

35. **Hulin BT**, **Gabbett TJ**, **Blanch P**, **Chapman P**, **Bailey D**, **Orchard JW**. Spikes in acute workload are associated with increased injury risk in elite cricket fast bowlers. *Br J Sports Med* 48: 708–712, 2014.

36. **Hulin BT**, **Gabbett TJ**, **Lawson DW**, **Caputi P**, **Sampson JA**. The acute: Chronic workload ratio predicts injury: High chronic workload may decrease injury risk in elite rugby league players. *Br J Sports Med* 50: 231–236, 2016.

37. **Jacobs I**. Blood lactate. Implications for training and sports performance. *Sport Med* 3: 10–25, 1986.

38. **Jennings, D., Cormack, S., Coutts, A. J., Boyd, L., & Aughey RJ**. The validity and reliability of GPS units in team sport specific running patterns. *Int J Sports Physiol Perform* 5: 328–341, 2010.

39. **Karvonen J**, **Vuorimaa T**. Heart rate and exercise intensity during sports activities. Practical application. *Sports Med* 5: 303–311, 1988.

40. **Kempton T**, **Sirotic AC**, **Coutts AJ**. An integrated analysis of match-related fatigue in professional rugby league. *J Sports Sci* 33: 39–47, 2015.

41. **Kohrt WM**, **Morgan DW**, **Bates B**, **Skinner JS**. PHYSIOLOGICAL RESPONSES OF TRIALTHLETES TO MAXIMAL SWIMMING, CYCLING, AND RUNNING. *Med Sci Sport Exerc* 17: 218, 1985.

42. **Kuipers H**, **Keizer HA**. Overtraining in Elite Athletes: Review and Directions for the Future. *Sport. Med.* 6: 79–92, 1988.

43. **Lehto M**, **Landry S**, **Buck J**. *Introduction to Human Factors and Ergonomics for Engineers*. Boca Raton, FL: CRC Press, 2007.

44. **Lippincott**, **Williams**, **Wilkins**. ACSM's Health-Related Physical Fitness Assessment Manual. In: , edited by Lupash E. Philadelphia, PA: Wolters Kluwer Health, 2014, p. 113–132.

45. **Malone S**, **Owen A**, **Newton M**, **Mendes B**, **Collins KD**, **Gabbett TJ**. The acute:chonic workload ratio in relation to injury risk in professional soccer. *J. Sci. Med. Sport* (2017). doi: 10.1016/j.jsams.2016.10.014.

46. **McAuliffe L**, **Parfitt G**, **Eston R**, **Gray C**, **Keage H**, **Smith A**. Combining perceptual regulation and exergaming for exercise rescription in low-active adults with and without cognitive impairment. *BMC Sports Sci Med Rehabil* 10, 2018.

47. **Mediciine AC of S**. ACSM'S Guidelines for Exercise Testing and Prescription. 2017.

48. **Meeusen R**, **Duclos M**, **Foster C**, **Fry A**, **Gleeson M**, **Nieman D**, **Raglin J**, **Rietjens G**, **Steinacker J**, **Urhausen A**. Prevention, diagnosis, and treatment of the overtraining syndrome: Joint consensus statement of the european college of sport science and the American College of Sports Medicine. *Med Sci Sports Exerc* 45: 186–205, 2013.

49. **Meister S**, **Faude O**, **Ammann T**, **Schnittker R**, **Meyer T**. Indicators for high physical strain and overload in elite football players. *Scand J Med Sci Sport* 23: 156–163, 2013.

50. **Morton RH**. Modelling training and overtraining. *J. Sports Sci.*: 1997.

51. **Morton RH**, **Fitz-Clarke JR**, **Banister EW**. Modeling human performance in running. *J Appl Physiol* 69: 1171–1177, 1990.

52. **Murray NB**, **Gabbett TJ**, **Townshend AD**, **Hulin BT**, **Mclellan CP**. Individual and combined effects of acute and chronic running loads on injury risk in elite Australian footballers. *Scand J Medicnine Sci Sport* 27: 990–998, 2017.

53. **Noble BJ**, **Robertson RJ**. *Perceived Exertion*. 1996.

54. **O'Connor PJ**, **Morgan WP**, **Raglin JS**, **Barksdale CM**, **Kalin NH**. Mood state and salivary cortisol levels following overtraining in female swimmers. *Psychoneuroendocrinology* 14: 303–310, 1989.

55. **Poole DC**, **Schaffartzik W**, **Knight DR**, **Derion T**, **Kennedy B**, **Guy HJ**, **Prediletto R**, **Wagner PD**. Contribution of exercising legs to the slow component of oxygen uptake kinetics in humans. *J Appl Physiol* 71: 1245–1260, 1991.

56. **Privette G**. Dynamics of Peak Performance. *J Humanist Psychol* 21: 57–67, 1981.

57. **Privette G**. Peak experience, peak performance, and flow: A comparative analysis of positive human experiences. *J Pers Soc Psychol* 45: 1361–1368, 1983.

58. **Privette G**, **Bundrick CM**. Peak Experience, Peak Performance, and Flow: Correspondence of Personal Descriptions and Theoretical Constructs , Journal of Social Behavior and Personality, 6:5 (1991:Mar.) p.169. *J Soc Behav Pers* 6: 169–188, 1991.

59. **PYNE DB**, **LEE H**, **SWANWICK KM**. Monitoring the lactate threshold in world-ranked swimmers. *Med. Sci. Sports Exerc.* (2001). doi: 10.1097/00005768-200102000-00019.

60. **Racinais S**, **Buchheit M**, **Bilsborough J**, **Bourdon PC**, **Cordy J**, **Coutts AJ**. Physiological and performance responses to a training camp in the heat in professional Australian football players. *Int J Sports Physiol Perform* 9: 598–603, 2014.

61. **Rhoades R**, **Bell D**. *Medical Physiology: Principles for Clinical Medicine*. Philadelphia, PA: Wolters Kluwer, 2009.

62. **Robinson DM**, **Robinson SM**, **Hume P a**, **Hopkins WG**. Training intensity of elite male distance runners. *Med. Sci. Sports Exerc.* 23: 1078–1082, 1991.

63. **Saltin B**, **Kiens B**, **Savard G**, **Pedersen P**. Role of Hemoglobin and Capillarization for Oxygen Delivery and Extraction in Muscular Exercise. *Acta Physiol Scand* : 21–32, 1886.

64. **Scherr J**, **Wolfarth B**, **Christle JW**, **Pressler A**, **Wagenpfeil S**, **Halle M**. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *Eur J Appl Physiol* 113: 147–155, 2013.

65. **Schoenfeld BJ**. The mechanisms of muscle hypertrophy and their application to resistance training. *J. Strength Cond. Res.* 24: 2857–2872, 2010.

66. **Scott MTU**, **Scott TJU**, **Kelly VG**. The validity and Reliability of Global Positioning Systems In Team Sport: A Brief Review. *J. Strength Cond. Res.* (2015). doi: 10.1519/JSC.0000000000001221.

67. **Shephard RJ**. Limits to the measurement of habitual physical activity by questionnaires * Commentary. *Br J Sports Med* 37: 197–206, 2003.

68. **Swart J**, **Jennings CL**. Use of blood lactate concentration as a marker of training status. *South African J Sport Med* 16: 3–7, 2004.

69. **Townshend AD**, **Worringham CJ**, **Stewart IB**. Assessment of speed and position during human locomotion using nondifferential GPS. *Med Sci Sports Exerc* 40: 124–132, 2008.

70. **Uchida MC**, **Teixeira LFM**, **Godoi VJ**, **Marchetti PH**, **Coutts AJ**, **Bacurau RFP**. Does

The Timing of Measurement Alter Session-RPE in Boxers ? *J Sport Sci Med* 13: 59–65, 2014.

71. **Uusitalo ALT**. Overtraining: Making a difficult diagnosis and implementing targeted treatment. *Phys. Sportsmed.* 29: 35–50, 2001.

72. **Varley MC**, **Fairweather IH**, **Aughey RJ**. Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *J Sports Sci* 30: 121–127, 2012.

73. **Wallace L**, **Slattery K**, **Coutts A**. The Ecological Validity andd Application of the Session-RPE Method for Quantifying Training Loads in Swimming. *J Strength Cond Res* 23: 33–38, 2009.

74. **Weiss KJ**, **Allen S V.**, **McGuigan MR**, **Whatman CS**. The relationship between training load and injury in men's professional basketball. *Int. J. Sports Physiol. Perform.* (2017). doi: 10.1123/ijspp.2016-0726.

75. **Whipp BJ**. Dynamics of pulmonary gas exchange [Online]. *Circulation* 76: VI18-28, 1987. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=3119250.

76. **Xu F**, **Rhodes EC**. Oxygen uptake kinetics during exercise. *Sport. Med.* 27: 313–327, 1999.

77. Track and Field Results Reporting System [Online]. 2018. https://www.tfrrs.org.

BIOGRAPHICAL SKETCH

EDUCATION

August 2017- August 2019 — Florida State University, Tallahassee, FL
Master's of Exercise Physiology, August 2019
Major: Sports Nutrition

August 2013- May 2017 — The University of Georgia, Athens, GA
Bachelor of Science in Family and Consumer Sciences, May 2017
Major: Dietetics
Overall GPA: 3.66/4.00
Major GPA: 3.77/4.00

CLINICAL EXPERIENCE

April- May 2019 — Food Service Management Rotation, Sodexo, FL

- 160 food service management hours for dietetic internship aiding a dietitian and head chef in the dining hall for athletes.
- Established an inventory system based on par values and price comparison.
- Assisted in budgeting for the dining hall and grab 'n go stations.

January- April 2019 — Sports Nutrition Rotation, Florida State University's Sports Nutrition

- 480 sports nutrition hours for dietetic internship aiding a dietitian.
- Provided nutrition counseling for athletes using evidence based nutrition and motivational counseling.

August- December 2018 — Community Rotation, Florida State University, Center for Healthy Advocacy and Wellness.

- 160 community hours for dietetic internship.
- Counseling patients using motivational interviewing techniques like mirroring and behavior modification techniques.
- Coordinated tabling events and cooking demonstrations. Created handouts, social media posts, and blog posts.

WORK EXPERIENCE

May 2019- Present — Research Assistant, Institute of Sports Science and Medicine, FL

- Leading data collection including blood draws, VO_2 max testing, and range of motion.
- Managing a group of undergraduate students assisting with the study.

August 2018- May 2019 — Teaching Assistant for Dr. Michael Ormsbee, Online Sports Nutrition, FL

- Maintaining webcourse on Canvas, a digital instruction platform.
- Successfully balancing meeting with students and patriating in graduate level course work.