

**EXAMINING ENERGY INDICES IN RECREATIONAL RUNNERS: AIMING TO
BETTER ADVISE PERIODIZATION**

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Chapter 1: Introduction

Recreational running is a widely implemented form of physical activity, and it continues to gain popularity due to the associated cardiovascular, musculoskeletal, and mental health benefits (Lavie et al., 2015; Smith et al., 2020). Running specifically triumphs over other forms of physical activity due to its simplicity—the activity lacks age restrictions, a need for a team or equipment, or technical training for a specific skill. Nevertheless, running is not a risk-free sport. Up to 92.4% of runners will experience a running-related injury, or RRI, each year (van Gent et al., 2007). RRIs diminish pleasure in exercise altogether and are associated with undesirable consequences, including temporary or permanent discontinuation of running (van der Worp et al., 2015). Around half of those injured will stop running for at least a year while others cease any form of physical activity indefinitely (Fields et al., 2010). For recreational runners, the annual rate of RRIs has remained high despite increasing attention towards injury prevention. Specifically, attention is currently given to intrinsic modifiable risk factors such as malalignment, tissue recovery times and procedures, and presumed injury-associated running techniques as well as extrinsic modifiable risk factors such as running surface, training errors, and shoe age, fit, and type (Aderem & Louw, 2015). Presently, researchers have only found evidence supporting the modification of one of these risk factors: training error.

Dr. Alan Hreljac summarized that “given a runner's specific anthropometric and biomechanical stride characteristics, the causes of all overuse running injuries could be classified as training errors, and thus all overuse running injuries should be preventable” (2005). The training error that recreational runners are most likely to encounter is “too

much, too soon”, making the line between experiencing improvements in performance and sustaining a RRI very fine. This fine line exists is because improvements to exercise performance and fitness are achieved by increasing training session volume and intensity, yet too great of an increase in overall training load can result in injury (Mallol et al., 2019).

The term “overreaching” is commonly used to describe brief increases in training volumes or intensities with the purpose of improving performance. “Functional overreaching” is overreaching that is accompanied by adequate recovery quality and durations, as well as the anticipated gains in performance. Overreaching is typically accompanied by an initial decrement to performance, but “non-functional overreaching” is overreaching from which the desired benefits are never realized (Rushall, 1990). “Overtraining” or “overtraining syndrome” are the terms coined for prolonged non-functional overreaching with many undesirable outcomes, including injury (Merrigan et al., 2020; Morgan et al., 1987). Successful training programs induce functional overreaching in order to generate desired performance improvements, but the highly-individualized gradient between functional overreaching and nonfunctional overreaching or overtraining makes training errors commonplace.

RRIs that result from training error are a result of an overaccumulation of tissue damage. This overaccumulation occurs as a result of the runner exposing themselves to a combination of tissue stress and frequency that exceeds their musculoskeletal system’s capacity (Edwards, 2018). Bones, muscles, tendons, and ligaments are living tissues that respond to the application of force with microdamage, repair, and remodeling; this process occurs due to a single bout of exercise while the runner is also

experiencing some magnitude of acute fatigue (Yang et al., 2013). With appropriate rest quality and time, tissues will eventually adapt so that they will be better prepared to encounter a force. On the other hand, an RRI may arise through repeated bouts of exercise due to nonfunctional overreaching or inadequate rest between applied bouts (van Gent et al., 2007). Unfortunately, cumulative tissue damage that yields RRIs is undetectable to the runner themselves prior to the onset of pain (Taunton et al., 2002). There are, however, other observable changes that take place in conjunction with fatigue, whether acute or cumulative, that can be measured and therefore perhaps give rise to means of preventing training errors from occurring.

As previously described, improvements in running performance and tissue damage occur progressively due to exercise during which the runner experiences acute fatigue, or an exercise-induced change in the ability to or means by which they produce force (Wan et al., 2017). Acute fatigue modifies runners' biomechanical and neuromuscular characteristics associated with the risk of experiencing an RRI, which include muscle strength, rate of force production in the muscle, muscle activation strategies, movement strategies, and the stiffness properties of the muscles and joints (Griffin et al., 2000; Rozzi et al., 1999). Fatigue corresponds with changes in a runner's kinematics, kinetics, and stiffness properties (Bonnard et al., 1994; Horita et al., 1996). Cumulative fatigue refers to the net effect of repeated bouts of exercise on force production and the accumulated tissue damage that is attenuating that ability (Edwards, 2018). An individual's perception of cumulative fatigue is also a strong indicator of RRI prevalence; Smith et al. (1997) showed that hockey players perception of cumulative fatigue measured during preseason and midseason strongly predicted injury rates over

the course of a season. As a runner experiences fatigue, whether acute or cumulative, one of the observable changes that occurs is to their stiffness properties—vertical stiffness and therefore the runner’s utilization of the stretch-shortening cycle (SSC) decreases (Horita et al., 1996).

Changes in an individual’s peak countermovement jump height have previously been calculated as an indicator of changes in stiffness and therefore SSC utilization (Struzik & Zawadzki, 2013). Furthermore, longitudinal mental health model research points to a dose-response relationship between mood state questionnaire responses and training load (Morgan et al., 1988). Unlike running gait kinematics, kinetics, and stiffness characteristics, changes in peak vertical jump height and mood state can be easily measured outside of the laboratory. If a relationship between the known variables correlated with the onset of RRIs and easily-attained vertical jump height can be well-established, recreational runners may be able to better-assess their cumulative fatigue state along the continuum between overreaching and overtraining. With better knowledge of their cumulative fatigue state, recreational runners could then modulate their training volume and intensity accordingly, avoiding training errors that result in RRIs.

Statement of the Problem

Currently, recreational runners do not possess a tool to determine whether their training load is that which is appropriate for improvements to performance rather than conducive to incurring an RRI. Over the course of a training regimen intended to improve performance, the runner experiences some magnitude of cumulative fatigue that is measurable and may correlate with the cumulative tissue damage the runner is

sustaining (Wender et al., 2022). The presence of fatigue has been shown to coincide with changes to an individual's measurable running mechanics and mood state, and the observable changes to their gait and mood state are present—even after a typical training session (Paquette et al., 2020; Puetz et al., 2006; Raglin et al., 1991; Riazati et al., 2020; van der Worp et al., 2015).

Purpose of the Study

The purpose of the study is to assess if recreational runners demonstrate a relationship between change in peak countermovement jump height or change in mood state and training program deviation occurrence measured throughout a progressive 13-week running training regimen.

Specific Aims and Hypotheses

Specific Aim #1: Examine the relationship between the change in peak countermovement jump height and training program deviation occurrence during a 13-week running training program in recreational runners.

Research Hypotheses for Specific Aim #1: Increasing peak countermovement jump height will be negatively associated with incidences of training program deviation occurrence, and decreasing peak countermovement jump height will be positively associated with incidences of training program deviation occurrence during a progressive 13-week running training program in recreational runners.

Specific Aim #2: Examine the relationship between mood state measures (Fatigue T-score, Vigor T-score, Energy Index, and Total Mood Disturbance) and training program deviations during a 13-week running training program in recreational runners.

Research Hypotheses for Specific Aim #2: Training program deviations will be negatively associated with the Energy Index and Vigor T-score and positively associated with the Fatigue T-score and Total Mood Disturbance.

Significance of the Study

A recreational runner's peak countermovement jump height and/ or their mood state derived from a questionnaire may provide them with an accessible surrogate measure of their cumulative fatigue status. By improving a runner's ability to monitor cumulative fatigue, one may also be decreasing that individual's likelihood of experiencing an RRI. With this information, a runner would be able to identify whether they should decrease, maintain, or increase their training volume and intensity to prevent an RRI and suffering the outcomes associated with RRI events.

Delimitations

1. Subjects are healthy recreational runners between the ages of 18 and 40 who are either new to or returning to running but have been running at least 3-20 miles consistently for at least 3 months prior to enrollment.
2. Subjects will be prescribed an individualized progressive running training program that will begin with the subject's self-reported weekly running mileage during the two weeks prior to enrollment (i.e. baseline mileage).
3. Adherence to the training program will be monitored using a daily running log and wrist-worn activity monitor.

Limitations

1. Kinematic data may be affected by movement artifact or variability on the placement of the retroreflective markers between sessions.
2. The results of this study can only be generalized to new or returning recreational runners who have been performing running training for more than three months.
3. All gait data will be acquired in a laboratory-setting rather than in the subject's typical training environment.

Assumptions

1. Subjects in this study are representative of recreational runners who have been performing running training for more than three months.
2. The running mechanics captured during the trials in the laboratory are representative of the subjects' running mechanics outside of the laboratory in their typical training environment.
3. External placement of the retro-reflective markers will not interfere with subjects' natural running gait.
4. Kinematic analysis assumes a Newton-Euler Rigid Link Model, and each segment has a fixed mass located at the segmental center of mass.
5. Joints are treated as frictionless hinge joints.
6. The running training and physical activity captured by the physical activity monitor represents all physical activity performed by the subjects.
7. The running training and physical activity reported by the subjects represents all physical activity performed by the subjects.

Abbreviations

- EI – POMS-derived Energy Index
- POMS – Profile of Mood States questionnaire
- POMS-M – Profile of Mood States questionnaire, modified
- RRI – running related injury
- SSC – stretch-shortening cycle
- TMD – POMS-derived Total Mood Disturbance
- QTM – Qualisys Track Manager software (Qualisys AB, Göteborg, Sweden)

Chapter 2: Review of Literature

Introduction

The intent of this research line of effort is to assist recreational runners with modulating their training regimen in order to prevent the occurrence of running-related injuries (RRIs) using measures that are readily-available and highly-individualized. This research is important given that experiencing an RRI often discourages a runner from continuing to be physically active. This study aims to investigate the potential relationship between the biomechanical variables related to fatigue and RRIs and more easily attainable metrics that are telling of the state of the runner. Specifically, the variables of interest are countermovement jump height and mood state questionnaire responses. Thus, the discussion points in this review are as follows: mechanics of running gait, acute fatigue, fatigue-related changes to running gait, overtraining, running-related overuse injuries, the vertical jump as a predictor of preparedness for exercise and injury, and questionnaire responses as a predictor of preparedness for exercise and injury.

Mechanics of Running Gait

Human locomotion is performed primarily using two gait modes: walking and running. The following traits characterize both modes of gait. Human gait is a repeated cycle termed a “stride”. Each cycle or stride begins when one foot makes initial contact with the ground and ends when that same foot contacts the ground again. Within this cycle, the encompassed leg experiences two main phases: a stance phase and a swing phase (Novacheck, 1998). The stance phase is the portion of the gait cycle during which the foot is in contact with the ground. The swing phase is the portion of the gait

cycle during which the foot is not in contact with the ground or “swinging” through the air. Regardless of the gait mode, stride length and stride frequency are commonly used to quantify an individual’s gait (Schubert et al., 2014). Stride length is defined as the distance traveled during a stride, and stride frequency is defined as rate at which strides are completed (Anderson et al., 2022). Because stride frequency is expressed as a rate, and therefore the inverse of the time the individual takes to complete a stride, gait velocity is the product of stride length and stride frequency.

When humans walk, at least one foot is in contact with the ground throughout a stride, and brief periods of time at the beginning and end of the cycle are spent in double-support, with both feet in contact with the ground (Williams & Martin, 2019). Running is distinguishable from walking because of the presence of an aerial (also called float or flight) phase during which neither foot is in contact with the ground. Furthermore, the spatiotemporal variables differ between the two modes; the stance phase is longer in walking than in running, the swing phase is conversely shorter in walking than in running, and stride rate and stride frequency are greater during running (Saibene & Minetti, 2003).

Using optical motion capture, researchers can record three-dimensional kinematic data that quantifies an individual’s running gait. Three kinematic quantities that are modulated consciously and subconsciously by the runner and often discussed in literature due to the ease at which they are measured without motion capture are speed, stride length and stride frequency. Biomechanists are also interested in quantifying joint angles at defined gait events, such as rearfoot eversion angle or knee abduction angle at heel-strike (Mousavi et al., 2021). These variables do require motion

capture to determine and are modulated subconsciously by the runner. With this understanding, researchers can observe variability between individuals as well as differences that arise within an individual as they become more trained, experience fatigue, change running surfaces, or experience an injury (Boullosa et al., 2020).

Running is mechanistically modeled in the leg as a spring-mass system, where the “mass” is the body and the “spring” has elastic properties representative of the muscles, ligaments, tendons, cartilage and bones (Latash & Zatsiorsky, 1993). The model consists of the center of mass above a single, linear spring connecting the center of mass to the foot. During a stride, the center of mass moves in a pendular motion above its pivot point, the foot—thus, the spring-mass system is an inverted pendulum. The spring compresses when any part of the foot first makes contact with the running surface and thus stores elastic potential energy that is returned at toe off during the stance phase of gait. In Figure 1., L_0 represents the initial and uncompressed length of the spring at initial contact with the ground, and ΔL represents the change in the length of the spring due to the compression it undergoes during midstance.

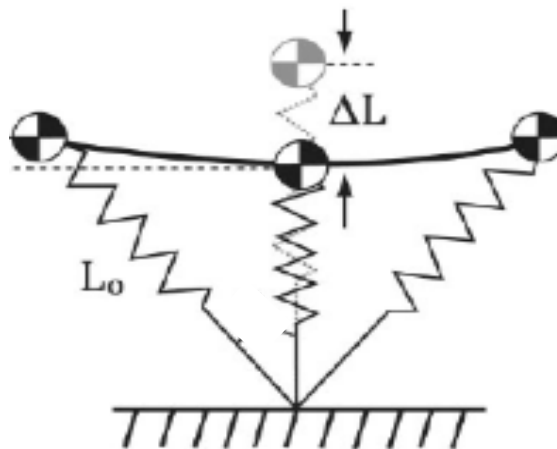


Figure 1. Spring-Mass Model of Running Illustration (Arellano & Kram, 2014)

The lengthening and shortening of the springs, or elastic components, of the legs allows humans to produce mechanical energy; this cycle is called the stretch-shortening cycle (SSC). The SSC is a rapid, cyclical muscle action during which an eccentric muscle contraction causing shortening of the muscle tendon unit is followed by a concentric muscle contraction causing lengthening of the muscle tendon unit. Potential elastic energy is stored by passive structures, including tendons and muscle sheaths during lengthening, which can then supplement the energy produced by the active muscle during subsequent shortening. The passive elastic, or strain energy returned contributes to the sum total mechanical energy produced by the muscle tendon unit during the concentric phase of muscle work. Tissues that passively contribute mechanical energy also reduce the metabolic energy required for movement of their muscle tendon unit (Struzik, 2021).

Greater deformation of the leg or displacement of the center of mass due to a maximum vertical force are indicative of greater spring compliance, or elasticity, and a more compliant limb. There is an undefined range of elasticity that is required for human movement and harnessing the passive energy return of the SSC. Generally though, less lower extremity elasticity is associated with generally desirable outcomes such as increased running velocities, increased maximal force output, and decreased metabolic energy requirements; however, too little elasticity can lead to musculoskeletal injury (Dutto & Smith, 2002; McMahon & Cheng, 1990). Another movement that harnesses the SSC is the countermovement jump, which is characterized by a preparation to jump that lengthens the muscle tendon units as the individual squats down followed

immediately by a maximal vertical jump due to the rapid and immediate shortening of the same muscle tendon units.

The different means by which biomechanists quantify characteristics of human gait allow researchers to investigate changes in gait that occur due to a vast number of internal and external stimuli and conditions. One condition that is well-researched is after a bout of fatigue-inducing exercise. Thus, by comparing the relationship between fatigue and changes in running gait to the changes observed in other variables, additional indicators of fatigue could be identifiable.

Acute Fatigue

Acute fatigue is fatigue which occurs due to a single bout of exercise, such as one typical training run. Acute fatigue is often generalized as either central or peripheral fatigue. Central fatigue refers to whole body feelings of weakness and energy deprivation and is thought to originate from the central nervous system. Peripheral fatigue refers to feelings that a specific muscle or muscle group is impaired or unable to initiate a muscle contraction that originates from the periphery, at or distal to the neuromuscular junction (Enoka, 1995). While these operational definitions are agreed upon, measuring them independently or even cumulatively when conducting research with human subjects still proves challenging. These challenges arise from the checks and balances in place prior to the onset of force production, involving cortical, neural, metabolic, and structural inputs (Riazati et al., 2020; Wan et al., 2017). Regardless of the source of the fatigue an athlete is experiencing, the associated outputs are generalized to be due to fatigue—thus, fatigue henceforth will refer to the cumulative product of both central and peripheral fatigue.

Acute fatigue, in exercise science literature, is often used synonymously with acute exhaustion resulting from an intense bout of exercise that ends when the individual can no longer continue or when certain physiological measurements of exhaustion have been reached (Enoka, 1995). Acute fatigue is accompanied with physiological, proprioceptive, and cognitive changes that cause changes in individuals' running gait pattern (Bailey et al., 2020; Rozzi et al., 1999). It appears that there may be an inverse relationship between these changes and the musculoskeletal system's protective mechanisms against injury (Borgia et al., 2022).

Fatigue-Related Changes to Running Gait

The human body is designed to adapt to different internal and external stimuli; however, adaptations to running-induced fatigue appear to be associated with the onset of RRIs (Fields et al., 2010). Increases in an individual's peak hip adduction angle, peak rearfoot eversion angle and peak knee internal rotation angle are kinematic changes observed during fatigued running and have also been positively correlated with incidences of RRIs such as iliotibial band syndrome, patella-femoral pain syndrome and medial tibial stress syndrome (Aderem & Louw, 2015; Ferber et al., 2010; Foch et al., 2015). During fatigued running, runners alter their stride characteristics by running with longer stride lengths and decreased stride frequency to maintain a constant running velocity (Struzik et al., 2021). These changes in the runner's gait at a given running speed also result in longer times in stance. (Clansey et al., 2012; Dutto & Smith, 2002).

The increase in muscle tendon unit elasticity that occurs with fatigue is primarily due to increases in displacement of the center of mass, because of longer stride lengths, and not due to increases in the peak vertical ground reaction force that is

inducing the spring deformation (Dutto & Smith, 2002). Because increased muscle tendon unit elasticity is associated with decreased maximal force output, one would expect that an individual's peak countermovement jump height would be greater before a fatigue-inducing bout of running than immediately after. Performance improvements cannot be attained without overreaching, or training at volumes and intensities that exceed what was done previously. Thus, it is important to monitor changes to an individual's gait or other variables that reliably coincide with these changes as they are occurring so that deleterious effects of training can be mitigated.

Functional, Nonfunctional Overreaching and Overtraining

Training regimens are programmed to gradually increase in volume or intensity with the expectation to result in improvements to performance (Mallol et al., 2019). When higher physiological demands are placed on the musculoskeletal system than the tissues were previously accustomed to, microtrauma occurs. This microtrauma is not inherently an injury, but rather a necessary step in the biological adaptation muscles undergo to prepare to withstand higher mechanical demands in the future (Laumonier & Menetrey, 2016). While these tissues recover, the runner will likely, but won't always, experience a fatigue-driven decline in their performance; however, after appropriate rest and tissue remodeling is accommodated, the desired gains in performance will be achieved as a result of supercompensation to functional overreaching (Bellenger et al., 2021).

Regardless of whether an athlete is recreational or professional, they are likely to experience periods of cumulative fatigue. This fatigue can be due to poor diet, poor sleep, psychological distress, cumulative training load or, as is most often observed, a

combination of these. Periods of high-fatigue negatively effect the recovery that must take place between bouts of acute fatigue (Meeusen et al., 2013). It is critical that athletes are able to accurately categorize their training state as functional or non-functional overreaching (Buchheit, 2014). This information will advise proper recovery and facilitate super-compensatory performance improvements before the accumulation of training-induced fatigue gives rise to the more severe conditions of non-functional overreaching and overtraining, which can lead to extended periods (i.e., weeks to months) of attenuated performance (Meeusen et al., 2013).

“Overtraining” or “overtraining syndrome” are the terms coined for prolonged non-functional overreaching with many undesirable characteristics and outcomes, to include RRIs (Merrigan et al., 2020; Morgan et al., 1987). Performance decrement due to overtraining lasts longer than two months, and the triggers typically include stressors like those previously mentioned in addition to an excessive training load (Meeusen et al., 2013; Meeusen et al., 2006). For the reasons described above, overtraining presents similarly to acute fatigue, but is long-term or cumulative. Given the severity of overtraining symptoms and the resulting impairment to quality of life, prevention of overtraining syndrome should be paramount to all endurance athletes (Kreher, 2016).

Running Related Injuries

Annual healthcare costs in the United States averaged around \$1.05 trillion over the last decade with an estimated \$131 billion associated with physical inactivity (Carlson et al., 2015). Recreational running is a popular form of physical activity, but many people who could participate and reap the health benefits it provides are deterred due to having experienced an RRI in the past. Up to 92.4% of runners will experience a

RRI each year (van Gent et al., 2007). More than 40 million people in the United States are participating in running, and at a RRI incidence rate of 26.0-92.4%, millions of people have experienced an RRI (Videbæk et al., 2015). Half of the runners who experience a RRI stop running for at least a year and some stop running or being physically active altogether; therefore, RRI can become a financially costly problem with long term health consequences (Fields et al., 2010).

Currently, researchers strive to identify modifiable risk factors for experiencing an RRI and mitigate these risk factors using gait retraining and training load manipulations aimed at preventing training errors (Hreljac, 2005). The identified intrinsic modifiable risk factors include malalignment, tissue recovery times and procedures, and presumed injury-associated running techniques. The identified extrinsic modifiable risk factors include running surface, training errors, and shoe age, fit, and type (Aderem & Louw, 2015). Inconsistent evidence suggests that RRIs are associated with specific biomechanical stride characteristics—some of which are greater stride rates, greater knee flexion angles at contact, and greater vertical loading rates (Willwacher et al., 2022). In addition to the inconclusive findings surrounding which biomechanical characteristics to retrain, researchers have found that gait retraining interventions result in lasting changes to their targeted mechanisms but do not reliably mitigate injuries (Esculier et al., 2018). RRI mitigation has been found to be more reliably correlated with modifications to training load aimed at preventing training error (Borresen & Lambert, 2009; Doyle et al., 2022; Willwacher et al., 2022).

Improvements to exercise performance and fitness are achieved by increasing training load by increasing training session volume and intensity—or overreaching

(Mallol et al., 2019; Rushall, 1990). Athletes, especially recreational athletes who lack coaches and other support staff who can monitor their training loads, lack the tool needed to accurately categorize their training state as functional or non-functional overreaching (Buchheit, 2014). Unfortunately, this means they also lack the tool needed to identify whether or not their training load is placing them at a higher risk of experiencing an RRI prior to the onset of pain (Taunton et al., 2002).

Running gait kinematics, kinetics, and stiffness characteristics change during a typical bout of running training, and these changes are proportionately and adversely related to the musculoskeletal system's protective mechanisms against RRI (Borgia et al., 2022). If a relationship between these changes and readily-accessible measurements can be established, monitoring the latter could serve as the tool recreational runners need to better protect themselves against RRI. For example, changes in peak vertical jump height and mood state can be easily measured outside of the laboratory and do not require special training or equipment to analyze.

The Vertical Jump as a Predictor of Preparedness for Exercise, Central Fatigue, and Injury

A countermovement jump is normally characterized by a preparation to jump—shortening phase—followed by an immediate maximal vertical jump. It therefore harnesses the force production of the SSC—the muscles are elongated during the eccentric “squat” phase and then immediately shortened during the concentric “jump” phase. Peak height achieved from a countermovement jump is a commonly-used metric for anaerobic performance, fatigue-related decrement to anaerobic performance, and readiness for increased training loads in weightlifting and other power-focused sports

(Orr et al., 2016; Watkins et al., 2017). These uses arose because peak countermovement jump height can be a valuable instrument of explosive lower-body power and strength (Watkins et al., 2017). Recently, the countermovement jump's applicability has been extended into aerobic performance—specifically, peak jump height as an indicator of fatigue because of the reliance of both gait and the countermovement jump on the strength shortening cycle (Merrigan et al., 2020).

Two studies have indicated decreases in peak vertical jump height, their surrogate for lower-extremity power, following a submaximal endurance training event. Both associated this decline in performance directly with knee extensor muscle fatigue (Fallowfield et al., 2012; Rodacki et al., 2002). Byrne and Eston (2002) observed similar findings whereby vertical jump performance decreased immediately following an exercise bout and remained reduced for up to four days. The prolonged decline in performance may have been indicative of prolonged fatigue. Orr et al. (2016) summarized that individuals with lower levels of strength and power would have to work at a higher intensity to maintain a given intensity when compared to stronger individuals. As such, when performing the same training, those with lower levels of strength and power are likely to fatigue sooner in a clinical setting (Markov et al., 2022). Considering this, with leg power reduced by exercise, there is the potential for an injury to occur either during or for up to a brief time after a training event particularly in recreational runners.

Questionnaire Responses as a Predictor of Preparedness for Exercise, Central Fatigue, and Injury

The POMS questionnaire was developed via factor analysis and published in 1971, and its pioneering has since been repeatedly replicated with larger and more diverse samples (O'Connor, 2004). In his 2004 "Evaluation of four highly-cited energy and fatigue mood measures", Patrick O'Connor summarized that the reliability of the fatigue and vigor scales is acceptable and reported internal consistency values ranging from 0.90 to 0.94 for fatigue and 0.87 to 0.92 for vigor. There is no normative data available that is representative of the general population, and most studies use repeated measures to analyze their results; however, sport scientists have since identified a distinct dose-response relationship between training intensity and mood state in endurance sports such as distance running (Raglin & Morgan, 1994). Currently, the POMS Questionnaire is regarded as an extremely valuable tool for those interested in monitoring athletes' recovery status because it allows one to quantify psychological (changes in mood, depression, anxiety) and physical (fatigue, vigor, tiredness, etc.) indicators of overtraining in athletes (Raglin & Kentta, 2011).

The individual measures included in the POMS questionnaire (tension, depression, anger, fatigue, confusion, and vigor) also exhibit dose-response patterns, apart from tension. Raglin et al. (1991) found that POMS tension did not decrease during tapers in college swimmers, likely due to the stress of the upcoming end of season races. Depression, anger, fatigue, confusion, and vigor responded positively to training load reduction. An individual's total mood disturbance (TMD) score is calculated by summing the totals for the negative subscales (tension, depression, fatigue,

confusion, anger) and then subtracting the totals for the positive subscale (vigor). Higher scores for the total mood disturbance score indicate a greater degree of mood disturbance. More recently, researchers have begun calculating and interpreting athletes' energy index (EI), a value indicative of the individual's subjective energy status. This value is equal to the sub-score for fatigue subtracted from the sub-score for vigor (Kenttä et al., 2006). Higher energy indices are observed at the beginning of training and during the high-competition period of training, which is accompanied by a training taper. By measuring mood states throughout a training regimen, periods of overreaching and overtraining should be distinguishable and therefore able to be addressed.

Summary

Recreational runners are endurance athletes that, given the negative physical, overall health, and psychological outcomes associated with RRIs and overtraining, should prioritize mitigating experiencing them over all else (Kreher, 2016). Measuring gait parameters that suggest an impending RRI is not possible for the forty million people who participate in running for exercise, but perhaps there are other more accessible tools available. A recreational runner can easily measure their peak countermovement jump height or mood states during training, and potentially therefore be advised whether their training is characterized by functional overreaching, nonfunctional overreaching, or overtraining.

Chapter 3: Methods

Participants, Inclusion and Exclusion Criteria, and IRB Approval

Recreational runners, ages 18-40, were recruited from the Indiana University-Bloomington campus and the surrounding community. During recruitment, potential subjects were screened verbally or via email using the following criteria: participants were included if: a) they began running at least three months prior to enrollment, b) were 18-40 years of age at the time of enrollment, c) could run continuously for 20 minutes, and d) ran an average of 3-20 miles per week. Participants were excluded if: a) they had suffered a lower limb or back injury in the six weeks prior to enrollment that caused them to decrement or cease their running training, b) they had a history of back or lower extremity surgery, c) they had a history of neurological or musculoskeletal pathologies or diseases, or d) they had a history of cardiovascular or pulmonary disease.

Enrollment

Potential subjects arrived at the Indiana University Biomechanics Laboratory for study enrollment. The study procedures were verbally explained, and their questions were answered fully before obtaining informed consent. Each subject provided written informed consent before physical readiness and running training screening or testing procedures began (Appendix A). The Indiana University Institutional Review Board approved the protocol for this study prior to the commencement of recruitment. Subjects' readiness to perform physical activity was assessed prior to beginning the study protocol using a modified version of the American College of Sports Medicine Exercise Pre-Participation Health Screening (Riebe et al., 2015) (Appendix B). The

subjects also self-reported their current running behaviors and were included in the study if they met the running habit and health-related inclusion criteria described as screening criteria.

Subjects were then asked to complete the Profile of Mood States (POMS) questionnaire to capture a summary of their mood states during the two weeks prior to enrollment, including that day (Appendix C) (McNair, 1971). A running training, physical activity, and injury history questionnaire (Appendix D) was completed to once again check that they met inclusion criteria.

Following enrollment procedures, subjects were given a thirteen-week running training regimen in which the volume of the training was progressively increased over the course of the protocol. Training volume during the baseline week (week 1) was based on the individual subject's training volume upon enrollment. Weeks 2-13 of the program were segmented into three four-week cycles as listed below. After discussing their usual running schedule and training habits, the researcher designed and administered the prescribed running training program for this study (Appendix E) based on their current mileage and number of runs per week with the following load progression:

- Week 1: normal mileage
- Week 2, 3, 4: increased mileage by 10% each week, relative to the previous week
- Week 5: decreased mileage by 20%, relative to the previous week
- Week 6, 7, 8: increased mileage by 10% each week, relative to the previous week
- Week 9: decreased mileage by 20%, relative to the previous week
- Week 10,11, 12: increased mileage by 10% each week, relative to the previous week
- Week 13: decreased mileage by 20%, relative to the previous week

The subjects were instructed to complete a daily running log (Appendix F) and to wear a provided activity monitor (Fitbit Inspire, Google LLC, Mountainview, California). Both tools were implemented to allow the researchers to monitor program-adherence and injury occurrence. Lastly, the subjects were instructed to complete a Modified POMS questionnaire at the end of the 4th, 8th, and 12th week (these weeks were characterized by the highest volume of running they had experienced to date), and at the end of the 5th, 9th, and 12th week (these weeks were characterized by a decrease in training volume).

Laboratory Visits

The subjects visited the biomechanics laboratory three times, during which motion capture data was collected: at the beginning of Week 1 (baseline), immediately following Week 4 (post-loading cycle), and immediately following Week 12 (post-peak loading cycle). The following steps were taken during each of the three visits.

Subject Preparation

The subjects wore spandex shorts and a form-fitting shirt. The researcher collected height and weight, then the subjects donned their personal running shoes. Tracking markers were placed bilaterally atop the running shoes on the distal end of the first phalanges, top of the feet, the anterior superior iliac spines, and the posterior sacral iliac spines. Tracking markers affixed non-colinear to ridged plates were positioned bilaterally on the lateral thighs, lateral legs, and on the shoe over the posterior calcanei. Additional calibration markers were placed after the treadmill warm-up bilaterally on the iliac crests, greater trochanters, medial and lateral femoral condyles, medial and lateral

malleoli, and on the heads of the first and fifth metatarsals. Individual markers were secured using utility tape and rigid plates were secured using wraps about the mid-thigh and the mid-leg.

Warm-up

The subjects then completed a brief warm-up in preparation for running. As part of this warm-up, the subjects ran for three to five minutes on a standard treadmill (Marquette 2000, GE Healthcare, Little Chalfont, United Kingdom) at 1% grade, with the speed of the treadmill belt concealed to the subject. After the warm-up, the remaining calibration markers were placed as described above.

Preferred Speed Identification

During the first visit, the researcher set the treadmill belt speed either above or below the subject's reported preferred pace then manipulated the speed, asking the subject whether it felt too fast or too slow for their longest typical running distance or duration. The belt speed was changed within 0.1-0.3 mph increments at random until the subject indicated the same speed as their preferred at least two times. This speed was used as the subject's preferred speed for all subsequent warm-ups and data collection events.

Vertical Jump & Gait Analysis Procedures

Bilateral, lower-body three-dimensional kinematic data were collected along an 18-meter level runway with a thirteen-camera optical motion capture system sampling at a frequency of 240 Hz (Oqus 400 series, Qualisys AB, Göteborg, Sweden). Three force platforms (AMTI OR6-6-2000, Watertown, MA) located in the center of the collection

volume were used to collect ground reaction force and center of pressure data at 1200 Hz. The camera and force platform coordinate systems were aligned such that the y-axis represented the anterior-posterior direction, the x-axis represented the medial-lateral direction, and the z-axis represented the vertical direction. Two sets of photoelectric sensors (TC-Gate, Brower Timing Systems, Draper, UT) were positioned six meters apart, equidistant from the center force platform and used to monitor running speed during motion capture measurements. The motion capture and force platform data were collected and synchronized using Qualisys Track Manager software (QTM) (Qualisys AB, Göteborg, Sweden).

Before the first running trial, the subject stood in quiet stance atop the center force plate while a two second standing calibration was collected. The trial was retained if the subject was still, and all calibration markers were observable throughout the data capture period. The calibration markers were then removed, and the subject remained standing on the center force plate.

Next, the subject completed two maximal countermovement jumps with the commands of “get ready” and “go”, as well as affirming feedback. For each jump, the subjects were coached to prepare to jump on “get ready” and then immediately, on “go”, quickly jump as high as they could using the countermovement strategy, attempting to touch a ball suspended from the ceiling with both of their middle fingers. The ball height was positioned at a height chosen subjectively based on their height and presumed jump height. The kinematic data of the markers placed on the posterior sacral iliac spines were collected during both jumps using the motion capture system.

The subject then performed overground running trials through the data collection space. With the commands of “get ready” and “go”, the subject ran down the center of the eighteen-meter runway at the preferred speed established during their first visit. The subject walked back to the starting position between trials. Trials were retained for analysis if the subject maintained a constant speed within the allowable speed through the data collection space (within $\pm 5\%$ error of their preferred speed) measured using photoelectric sensors, at least one foot made complete contact atop at least one of the three force plates, and an entire stride (stance + swing phase, or swing + stance phase) was captured by the motion capture system. Trials were repeated until ten stance phases of each leg are recorded. These measurements will henceforth be referred to as the pre-treadmill trials.

Following the pre-treadmill trials, the subject ran a prescribed distance or duration—depending on how they typically measure their runs—on the treadmill at 1% grade and their preferred speed. The distance or duration they ran were that which they identified as the longest but typical run they had been performing upon enrollment. During the treadmill run, the subjects were asked to rate how they were feeling on the 6-20 Borg Rating of Perceived Exertion (RPE) scale (Borg, 1982) at the end of the 3rd, 6th, and 10th minutes, then every five minutes thereafter as well as the final minute. Immediately following the treadmill run, the subject completed two maximal countermovement jumps in the same manner as previously described, then completed twenty consecutive overground trials in the same manner as previously described. However, for these running trials, each subject jogged back to the starting position between trials and every trial was retained for analysis, regardless of running speed or

foot placement on the force plates. The change in data collection strategy for these trials was made to ensure that they were completed as quickly as possible following the treadmill run. The subject was given feedback on time and starting position to improve trial-compliance with the criteria already discussed. These measurements will henceforth be referred to as the post-treadmill trials.

Immediately following the twentieth trial, the subject completed two final maximal countermovement jumps in the same manner as previously described. To account for the chance that the tracking markers may have moved during the protocol, the researcher re-placed the calibration markers and collected one additional standing calibration before removing the retroreflective markers from the subject.

Peak Countermovement Jump Height

For each countermovement jump trial, three-dimensional marker position trajectories were tracked using QTM (Qualisys, Inc., Gothenburg, Sweden). Peak countermovement jump height was calculated for every jump trial by subtracting the average z-coordinate (i.e., vertical) magnitude of the right posterior iliac spine retroreflective marker recorded during the first two second standing calibration from the peak z-coordinate magnitude of the same marker during the countermovement jump. These peak z-coordinate magnitudes were obtained by inspecting the .csv tables of raw kinematic data exported from QTM and recording the local z-coordinate maxima from the data. The maximum jump height attained for each of the three timepoints (pre-treadmill, post-treadmill, and final) were recorded.

Mood State Measures

The subject's POMS-M responses were converted from raw Likert scale data to T Scores using the POMS Profile Sheet for College Norms © 1971 Educational & Industrial Testing Service. Each vigor T Score and fatigue T Score was recorded and each Total Mood Disturbance (TMD) score and Energy Index (EI) was calculated. An individual's TMD score is calculated by summing the T Scores for the negative subscales (tension, depression, fatigue, confusion, anger) and then subtracting the T Scores for the positive subscale (vigor).

Training Program Deviations

Throughout the 13-week training program, each subject was assigned a weekly training volume (in minutes or miles) that they were expected to run. Although the subjects were assigned a recommended daily volume, the changes made within a week were not defined as training deviations if the weekly training volume was achieved. The subjects' justifications for the training deviations were extracted from the daily running log and were categorized as "subject ceased running training" or "subject decreased running training volume" and "due to pain or injury", "due to illness", "due to daily life stresses", or "due to the stress of an acute event".

Statistical Analysis

All analyses were conducted using the Statistical Package for the Social Sciences (SPSS, version 21; SPSS Inc., Chicago IL). Subject attrition prevented a statistical analysis to evaluate the relationship between the change in peak countermovement jump height and training program deviation (Specific Aim 1). A t-test

was performed to determine whether peak countermovement jump height was different across the three data collections among the three subjects who completed more than one data collection. Instead, these t-tests allowed the researcher to describe changes that did or did not occur coinciding with the periodization of the 13-week training program. A two-tailed Pearson Correlation was also performed in order to determine the correlation between mood state measurements (Fatigue T-score, Vigor T-score, EI, and TMD) and the change in mood state measurements between timepoints and training program deviations during a 13-week running training program (Specific Aim 2).

Chapter 4: Results

Six subjects consented to participate in this study, characterized in Table 2. Of these subjects, one individual completed only a portion of the first data collection and four weeks of the training program, two subjects completed the first data collection and four weeks of the training program, two subjects completed the first data collection and four weeks of the training program, one subject completed the first and second data collection and ten weeks of the training program, and two subjects completed all three data collections and the entire thirteen-week training program.

Subject	Sex	Age	Running Experience (years)	BMI (kg/m ²)	Weekly Training Load (miles)	Preferred Training Speed (m/s)
1	F	22	10	25.66	8	2.01
2	M	38	8	25.69	12	2.10
3	F	20	8	23.28	10	2.59
4	F	19	5	21.23	10	2.61
5	F	20	8	20.61	10	2.44
6	M	20	6	23.96	6	3.04

Table 2. Subject characteristics at the time of enrollment.

Training Program Deviations

Two subjects completed the 13-week training program without a training program deviation, and the other four subjects departed the training program entirely. Each subject's justification for the training program deviation(s) and the category in which their justification belonged are presented in Table 3.

Subject	Week of Deviation	Deviation Type	Category of Deviation
1	0	<ul style="list-style-type: none"> Did not complete 1st gait analysis 	pain (ankle)
	3	<ul style="list-style-type: none"> Ceased running training Dropped out 	daily life stressors (academic)
2	4	<ul style="list-style-type: none"> Ceased running training Dropped out 	daily life stresses (academic)
4	4	<ul style="list-style-type: none"> Ceased running training 	illness (>10 days)
6	10	<ul style="list-style-type: none"> Ceased running training 	daily life stresses (academic)

Table 3. The week, category, and description of each training program deviation. Deviations were categorized as “ceased running training” or “decreased running training volume” and the reason for the deviation was categorized as “due to pain or injury”, “due to illness”, “due to daily life stresses”, and/ or “due to the stress of an acute event”.

Aim 1: The Relationship between Changes in Peak Countermovement Jump Height and Training Program Deviation

Subject 3 and Subject 5 completed all three data collections and did not deviate from the running training program. Subject 6 completed two of the three data collections but deviated from the running training program. In order to examine the impact of cumulative fatigue, not acute fatigue due to the in-lab protocol, on countermovement jump performance, only the changes in peak pre-treadmill countermovement jump height were analyzed. The peak pre-treadmill countermovement jump height (mm) for Subject 3, Subject 5, and Subject 6 during the three data collections are reported in Figure 2.

For Subject 3 and Subject 5, peak countermovement jump height was similar ($r(1) = 1, p = .31$) between Week 1 (baseline; $height(S3) = 396.30\text{mm}$, $height(S5) = 349.01\text{mm}$) and Week 12 (post-peak loading cycle; $height(S3) = 400.11\text{mm}$, $height(S5) = 350.18\text{mm}$). Peak countermovement jump height was lowest for these two subjects during Week 4 (post-loading cycle; $height(S3) = 392.81\text{mm}$, $height(S5) = 344.19\text{mm}$). Although Subject 6 deviated from the training program and did not complete the third data collection, the difference in peak pre-treadmill countermovement jump height between Week 1 and Week 4 was similar to Subjects 3 and 5. Subject 6's Week 4 peak countermovement jump height (post-loading cycle; $height(6) = 537.86\text{mm}$) was lower than Week 1 (baseline; $height(6) = 549.91\text{mm}$). Statistically though, these differences between Week 1 and Week 4 was not statistically significant ($r(2) = 1, p = .12$). The remaining subjects did not complete successive data collections, which prevented a statistical analysis comparing peak countermovement jump height between weeks or assessing the association with training deviations.

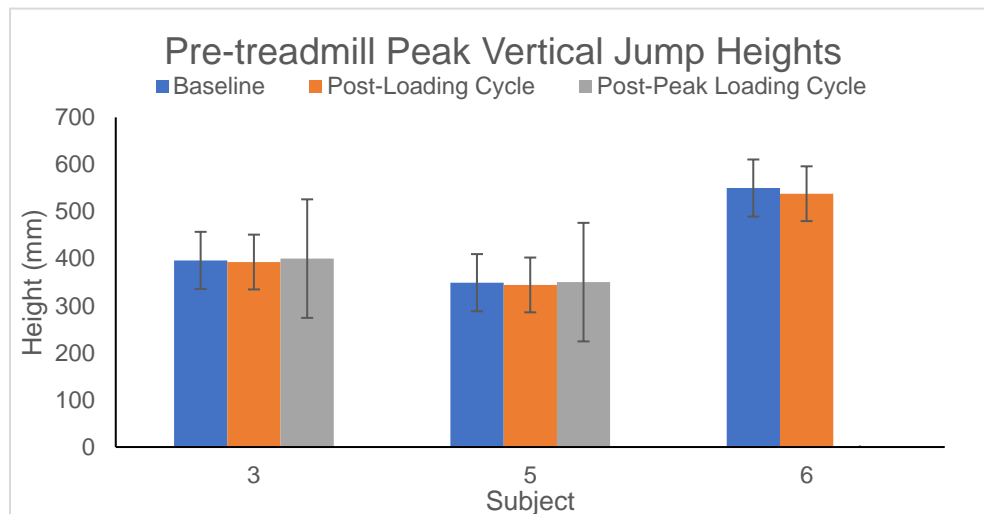


Figure 2. Pre-treadmill peak countermovement jump height for Subject 3, Subject 5, and Subject 6 across all three data collections (baseline, post-loading cycle, post-peak loading cycle). Error bars represent standard error.

Aim 2: The Relationship between Mood State Measures and Training Program

Deviations

Each subject's POMS and POMS-M derived mood state measures across the timepoints during which they were participating in the study are reported in Figure 3 through Figure 6.

Fatigue. The data collected during this study did not support a correlation between Fatigue T-score and training program deviation ($r(23) = .09, p = .93$); however, the data did support a moderate positive correlation between the change in Fatigue T-score and training program deviation ($r(9) = .49, p = .12$). The following discussion describes the changes that were observed in the subjects' Fatigue T-scores throughout their participation in the 13-week progressive running training program. Subject 1, Subject 2, and Subject 4 experienced a decrease in fatigue between baseline and the end of the first loading cycle ($\Delta F(S1) = -4, \Delta F(S2) = -9, \text{ and } \Delta F(S4) = -6$), then left the study. Subject 3, Subject 5, and Subject 6 experienced an increase in fatigue between baseline and the end of the first loading cycle ($\Delta F(S3) = 1, \Delta F(S5) = 2, \text{ and } \Delta F(S6) = 4$) followed by a decrease in fatigue between the end of the first training cycle and the first deload week ($\Delta F(S3) = -13, \Delta F(S5) = -3, \text{ and } \Delta F(S6) = -11$). Subject 3, Subject 5, and Subject 6 experienced an increase in fatigue between the first deload week and the end of the second loading cycle ($\Delta F(S3) = 13, \Delta F(S5) = 3, \text{ and } \Delta F(S6) = 5$) followed by a decrease in fatigue between the second loading cycle and the second deload week ($\Delta F(S3) = -3, \Delta F(S5) = -4, \text{ and } \Delta F(S6) = -9$). These fatigue scores closely matched their scores after the first deload week. Only Subject 3 and Subject 5 remained in the study for the final loading cycle, during which both experienced an increase in fatigue between

the second deload week and the third loading cycle week ($\Delta F(S3) = 4$ and $\Delta F(S5) = 3$), which was a smaller increase than during the second loading cycle. Between the end of the third loading cycle and the third deload week, Subject 3's fatigue T-score decreased by 4 and matched their score during the previous two deload weeks, and Subject 5's T-score increased by two and matched their score at baseline.

Vigor. The data collected during this study did not support a correlation between Vigor T-score and training program deviation ($r(23) = -.02$, $p = .93$); however, the data did support a moderately-strong negative correlation between the change in Vigor T-score and training program deviation ($r(9) = -.70$, $p = .50$). The following discussion describes the changes that were observed in the subjects' Vigor T-scores throughout their participation in the 13-week progressive running training program. Every subject but Subject 6 experienced a decrease in vigor between baseline and the end of the first loading cycle, while Subject 6 experienced a very slight increase in vigor ($\Delta V(S1) = -19$, $\Delta V(S2) = -9$, $\Delta V(S3) = -7$, $\Delta V(S4) = -8$, $\Delta V(S5) = -2$, and $\Delta V(S6) = 1$). Subject 5's vigor T-score remained between 41 and 44 on the 35-65 point scale throughout the remainder of the study. Subject 3 and Subject 6 experienced an increase in vigor between the end of the first loading cycle and the first deload week ($\Delta V(S3) = 8$ and $\Delta V(S6) = 5$), followed by a decrease in vigor between the first deload week and the second loading cycle ($\Delta V(S3) = -12$ and $\Delta V(S6) = -17$) which was restored between the end of the second loading cycle and the second deload week ($\Delta V(S3) = 9$ and $\Delta V(S6) = 14$). Subject 3 repeated this pattern once more; their vigor T-score decreased between the second deload week and the third loading cycle ($\Delta V(S3) = -6$), then increased between the third loading cycle and the third deload week ($\Delta V(S3) = 3$).

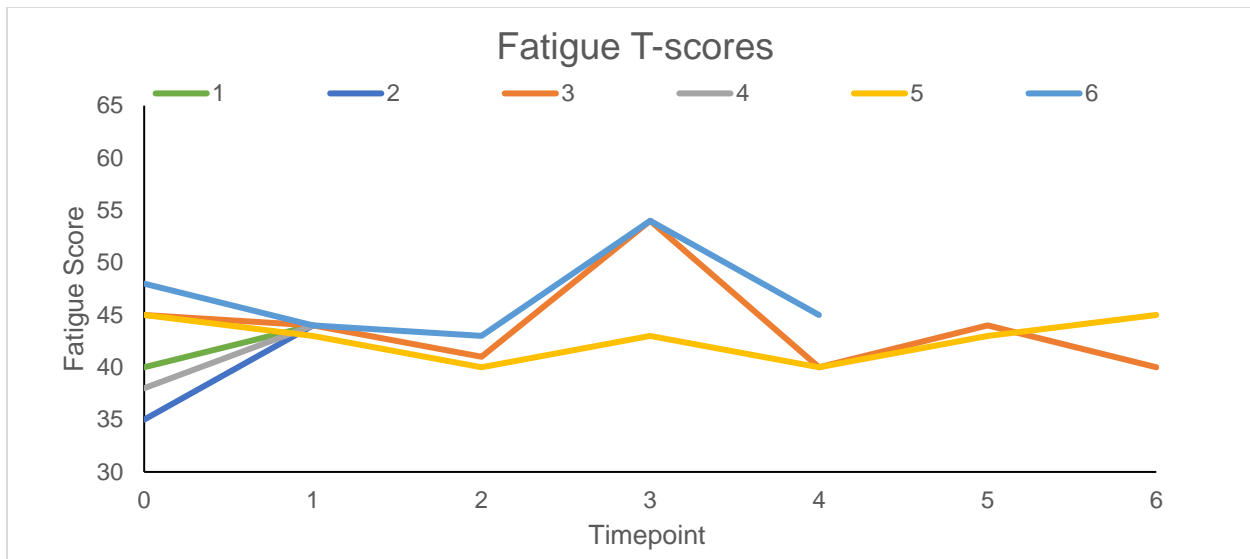


Figure 3. Fatigue T-scores of each subject over the course of the training program. Timepoint 0 represents enrollment, Timepoint 1 represents the completion of the loading cycle, Timepoint 2 represents the completion of the first deload week, Timepoint 3 represents the completion of the second loading cycle, Timepoint 4 represents the completion of the second deload week, Timepoint 5 represents the completion of the final loading cycle, and Timepoint 6 represents the completion of the final deload week.

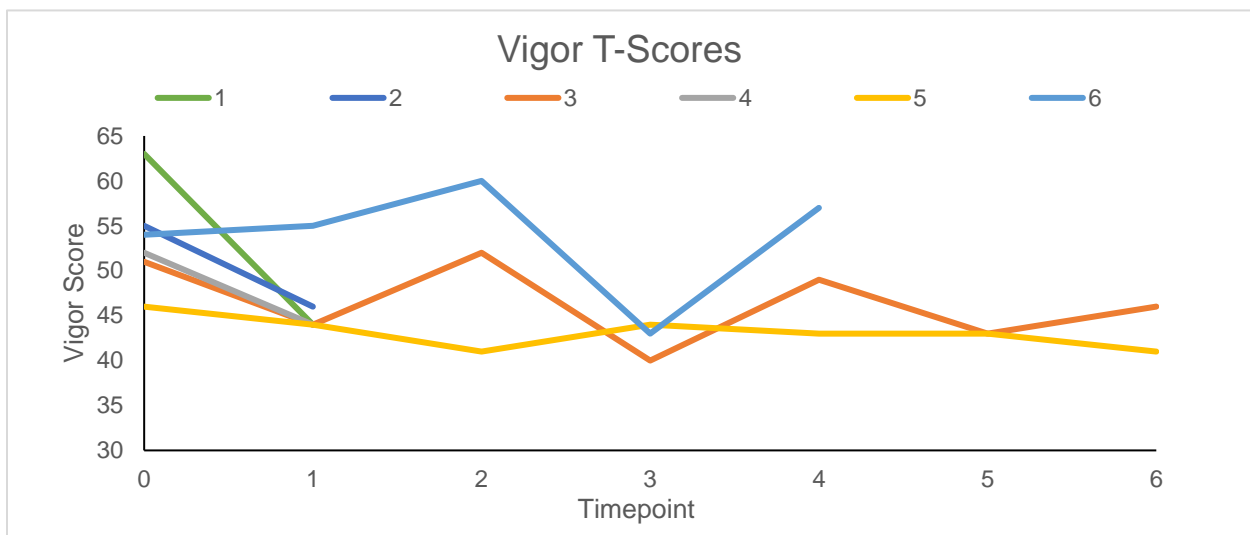


Figure 4. Vigor T-scores of each subject over the course of the training program. Timepoint 0 represents enrollment, Timepoint 1 represents the completion of the loading cycle, Timepoint 2 represents the completion of the first deload week, Timepoint 3 represents the completion of the second loading cycle, Timepoint 4 represents the completion of the second deload week, Timepoint 5 represents the completion of the final loading cycle, and Timepoint 6 represents the completion of the final deload week.

EI. The data collected during this study did not support a correlation between *EI* and training program deviation ($r(23) = -.05, p = .80$); however, the data did support a moderately-strong negative correlation between the change in *EI* and training program deviation ($r(9) = -.68, p=.50$). The following discussion describes the changes that were observed in the subjects' *EI* values throughout their participation in the 13-week progressive running training program. The greatest change in *EI* that occurred from one timepoint to the next was twenty-eight points (Figure 5); this change was observed in Subject 6. The following are the *EI* values calculated for Subject 6: *EI*=6 at baseline, *EI*=11 after the first loading cycle, *EI*=17 after the first deload week, *EI*=-11 after the second loading cycle, and *EI*=12 after the second deload week and upon their departure from the study. The second greatest change in *EI* that occurred from one timepoint to the next was observed in Subject 1 (*EI*=23 at baseline and *EI*=0 after the first loading cycle) upon their departure from the study. Subject 2 (*EI*=20 at baseline and *EI*=2 after the first loading cycle) and Subject 4 (*EI*=14 at baseline and *EI*=0 after the first loading cycle) departed the study after the first loading cycle as well.

The smallest change in *EI* that occurred from one timepoint to the next was zero points (Figure 5); this was only observed in Subject 5, who sustained minimal changes to *EI* throughout the study with the following values: *EI*=1 at baseline, *EI*=1 after the first loading cycle, *EI*=1 after the first deload week, *EI*=1 after the second loading cycle, *EI*=3 after the second deload week, *EI*=0 after the third loading cycle, *EI*=-4 after the third deload week. Subject 3 and Subject 6 generally demonstrated lower values for *EI* at the end of each loading cycle and higher values for *EI* at the end of each deload week. The following are the *EI* values calculated for Subject 3: *EI*=6 at baseline, *EI*=0 after the first

loading cycle, EI=11 after the first deload week, EI=-14 after the second loading cycle, EI=9 after the second deload week, EI=-1 after the third loading cycle, EI=6 after the third deload week. The following are the EI values calculated for Subject 6: EI=6 at baseline, EI=11 after the first loading cycle, EI=17 after the first deload week, EI=-11 after the second loading cycle, and EI=12 after the second deload week.

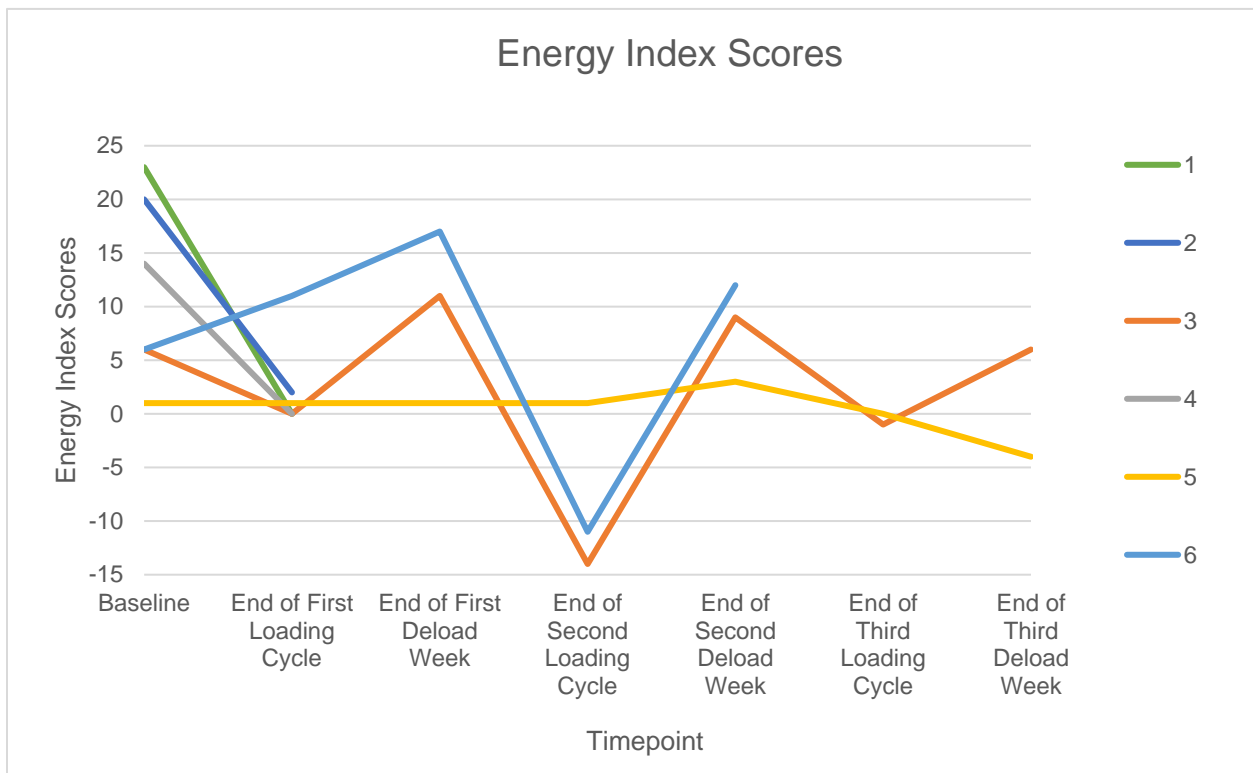


Figure 5. Energy Indices of each subject over the course of the training program.

TMD scores were inversely-related to the EI scores across all timepoints (Figure 6). The data collected during this study supported a weak correlation between TMD and training program deviation ($r(23) = .3, p = .77$); however, the data did support a strong positive correlation between the change in TMD and training program deviation ($r(9) = .85, p = <.001$). The following discussion describes the changes that were observed in

the subjects' TMD values throughout their participation in the 13-week progressive running training program.

Before departing the study, Subject 1, Subject 2, and Subject 4 demonstrated an increase in TMD ($\Delta\text{TMD}(S1) = 58$, $\Delta\text{TMD}(S2) = 48$, and $\Delta\text{TMD}(S4) = 53$). These three subjects had an average TMD value 42.3 points lower at baseline compared to the other three subjects ($\text{AverageTMD}(S1, S2, S4) = 131.6$ and $\text{AverageTMD}(S3, S5, S6) = 174$), yet their average TMD value after the first loading cycle was 19 points greater than those of the three subjects who were enrolled for the full thirteen weeks ($\text{AverageTMD}(S1, S2, S4) = 184.6$ and $\text{AverageTMD}(S3, S5, S6) = 165.6$). As with EI, Subject 5's TMD remained consistent compared to the other subjects. Subject 5's TMD values were as follows: TMD=173 at baseline, TMD=152 after the first loading cycle, TMD=164 after the first deload week, TMD=157 after the second loading cycle, TMD=162 after the second deload week, TMD=169 after the third loading cycle, TMD=175 after the third deload week. Unlike Subject 5, Subject 3's TMD values fluctuated throughout the training program—increasing at the end of each training cycle and decreasing after each deload week. Subject 3's TMD values were as follows: TMD=168 at baseline, TMD=172 after the first loading cycle, TMD=156 after the first deload week, TMD=194 after the second loading cycle, TMD=157 after the second deload week, TMD=172 after the third loading cycle, TMD=167 after the third deload week. As with their EI, Subject 6's TMD mirrored that of Subject 3 before their departure from the study.

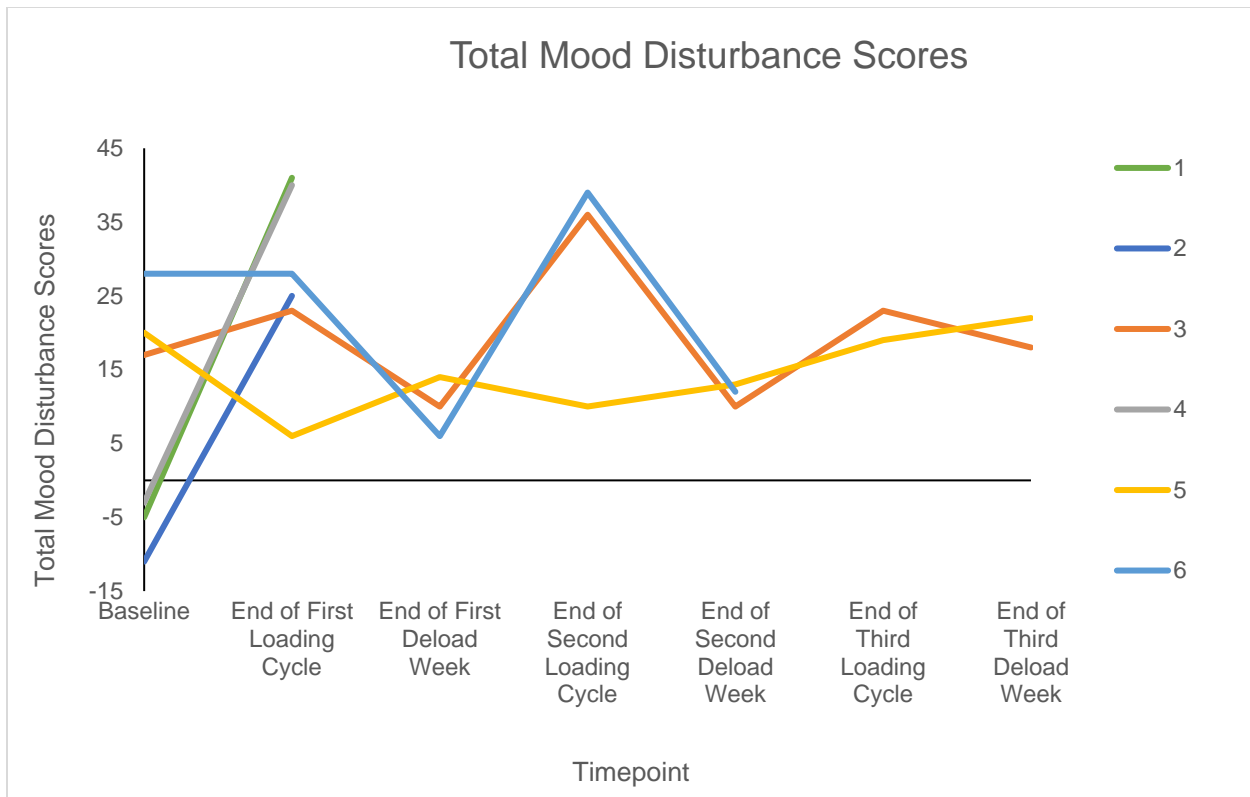


Figure 6. Total Mood Disturbances (TMD) of each subject over the course of the training program.

The mood state profiles of the two subjects who completed the 13-week training program, Subject 3 and Subject 5, are reported in Figure 7 and Figure 8. Figure 7 compares the subjects' mood state profiles at enrollment with their mood state profiles at the completion of each loading cycle (having completed the greatest training volume up to that timepoint), and Figure 8 compares their mood state profiles at enrollment with their mood state profiles at the completion of each deload week (having decreased their training volume by 20% the previous week).

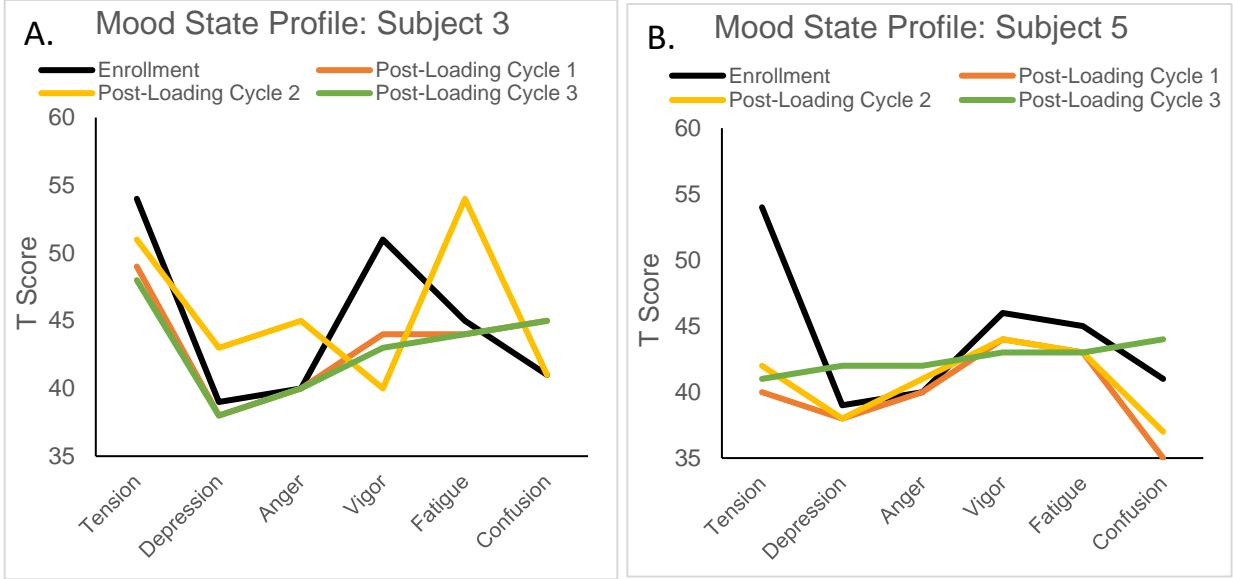


Figure 7. Mood state profile at enrollment and at the completion of each loading cycle for (A) Subject 3 and (B) Subject 5.

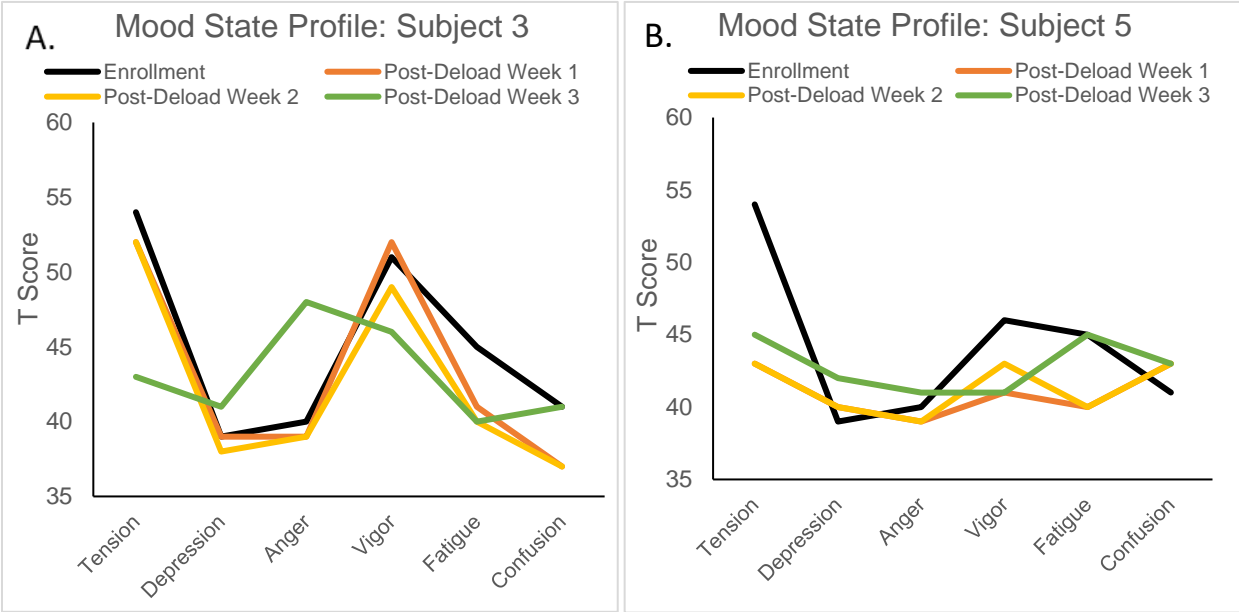


Figure 8. Mood state profile at enrollment and at the completion of each deload week for (A) Subject 3 and (B) Subject 5

Chapter 5: Discussion

The purpose of this study was to assess if recreational runners demonstrate a relationship between change in peak countermovement jump height or mood state and training program deviation occurrence measured throughout a progressive 13-week running training regimen.

Specific Aim #1: *Examine the relationship between the change in peak countermovement jump height and training program deviation occurrence during a 13-week running training program in recreational runners.*

Due to the small sample size recruited for this study and the volume of attrition that occurred after the first data collection, it is unclear whether decreasing peak countermovement jump height would have been positively associated with incidences of training program deviation occurrence during a progressive 13-week running training program in recreational runners. Although the differences that were observed in baseline peak countermovement jump height between data collections were not statistically significant, there was a distinguishable pattern that emerged among the three subjects who completed two or more data collections: the baseline peak countermovement jump height was smaller in Week 4 than at baseline.

The Week 4 data collection occurred after the first loading cycle and therefore immediately after the runners experienced a week of training at the highest training volume they had run up to that point. Byrne and Eston (2002) investigated the effect of exercise-induced muscle damage on countermovement jump performance as well as other performance-based variables. They found that a bout of muscle-damaging exercise (100 barbell squats in ten sets of ten repetitions at 70% body mass load)

decreased peak countermovement jump height to 95.2 +/-1.3% of their pre-exercise values. It is plausible that the progressive—10% each week, for four weeks—increase in training load that the subjects experienced induced the adaptation-priming tissue damage that is expected with functional overreaching and therefore a decrease in countermovement jump height performance.

It is also possible, however, that peak countermovement jump height is not negatively correlated to cumulative fatigue. Rodacki et al. (2002) found that acutely fatiguing the knee flexor muscles did not reduce peak countermovement jump height or the means by which the same jump height was achieved, and that acutely fatiguing the knee extensor muscles also did not reduce peak countermovement jump height despite reducing peak joint angular velocity, peak joint net moment, and power around the knee. Unlike this study or the Byrne and Eston study, Rodacki attempted to achieve acute peripheral fatigue only—likely preventing these researchers from observing changes to countermovement jump performance due to cumulative or central fatigue, as well as muscle damage.

Perhaps, with a larger subject population and more data collections for individuals who experienced training deviations, a clearer relationship would have been observed. The observed decline in countermovement jump performance from baseline to the end of the first loading cycle may have been greater for the individuals with training deviations, due to overtraining, than the subjects without, who still demonstrate a decrement to performance due to functional overreaching. Additionally, the peak countermovement jump heights of the subjects with training deviations may continue to

decline or remain reduced leading up to the training deviation, rather than returning to baseline, as was observed in this study's subjects without training deviations.

Specific Aim #2: *Examine the relationship between mood state measures (Fatigue T-score, Vigor T-score, Energy Index, and Total Mood Disturbance) and training program deviations during a 13-week running training program in recreational runners.*

Training program deviations were not associated with a specific range of T-scores for vigor or fatigue; however, training program deviations did correlate with greater changes in both T-scores—the four subjects who departed the study experienced a greater decline in Vigor T-score and a greater increase in Fatigue T-score than the subjects who continued with the progressive running training program beyond that timepoint.

Training program deviations were not associated with a specific range of EI or TMD values; however, training program deviations did correlate with greater changes in both values—the four subjects who departed the study experienced a greater decline in EI and a greater increase in TMD than the subjects who continued with the progressive running training program beyond that timepoint.

Foundational work by sport psychology researchers has demonstrated the application of monitoring mood state changes that occur in conjunction with changes to training volume in order to detect the risk of overtraining in endurance athletes (Morgan et al., 1987). Figure 9 is a depiction of the Iceberg Profile, which is a visual representation of some athlete's complete profile of mood states and characterized by a high score on the vigor scale accompanied by lower, but still positive, scores on the

other domains. The Iceberg Profile was labelled by Morgan in 1985 and has been shown to distinguish successful athletes from unsuccessful athletes. Furthermore, the Profile shape is disrupted with increased training volume. Morgan et al. (1987) observed a decrease in vigor T-scores and an elevation in T-scores for depression, anger, fatigue, and confusion corresponded with elevations in training yardage in male and female college swimmers.

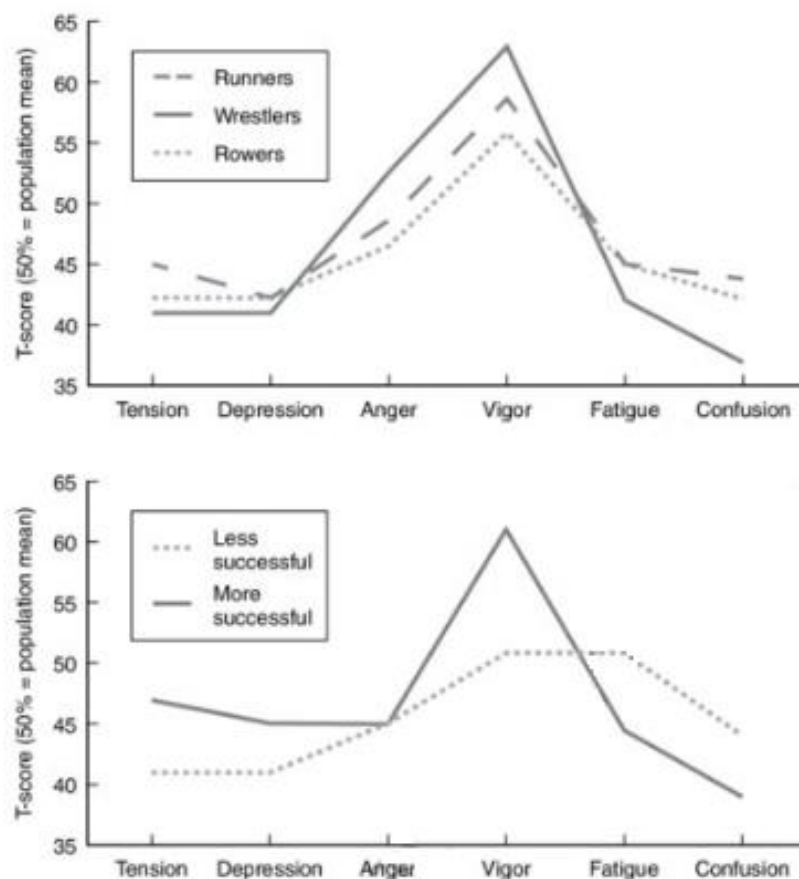


Figure 9. The iceberg profile of positive emotional health typically found in successful athletes. Adapted from W. Morgan, 1979, *Coach, athlete, and the sport psychologist* (Toronto: University of Toronto School of Physical Health and Education), 185. For educational purposes only. Do not reproduce.

In the same way, the subjects in this study demonstrated a significant decrease in vigor and a significant increase in fatigue, which resulted in a significant decrease in EI, with each peak in training volume. TMD also increased with each peak in training load, which was further illustrated in the changes to their mood state profiles depicted in Figure 7. Although the depression T-Score has been shown to be the least responsive to modifications to training load, the fact that the two subjects who completed the study did not experience varying depression T-scores suggests that they also did not experience overtraining syndrome (O'Connor et al., 1989).

Although they experienced mood state perturbations with each peak in training volume, the subjects who did not experience training program deviations also recovered from these perturbations at the end of each deload, or recovery, week. Compared to the mood state profiles of the subjects who did not deviate from the training program (Figure 7), the profiles of the subjects that did experience training deviation(s) (Figure 8) illustrate fewer deviations from their baseline profiles. These findings are consistent with the current literature on the POMS as an effective tool for distinguishing between functional overreaching and overtraining (Kenttä et al., 2006). When a recreational runner's mood states do not return to their baseline or recovery-associated values following a 3:1 mesocycle (three weeks of progressive weekly training load followed by one week of deload), they should recognize they are potentially experiencing overtraining and consider decreasing their training volume.

Chapter 6: Conclusion

A recreational runner's peak countermovement jump height and/ or their mood state derived from a modified Profile of Mood States questionnaire may provide those athletes with an accessible and convenient measure of their cumulative fatigue status. If a recreational runner can easily monitor cumulative fatigue and therefore distinguish between functional overreaching and overtraining, they can modify training volume and/or intensity to decrease their likelihood of experiencing an RRI without ceasing running training entirely.

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Appendix A: Informed Consent Document

INDIANA UNIVERSITY INFORMED CONSENT STATEMENT FOR

Changes in Running Gait Complexity Due to a 12-Week Progressive Running Training in Novice Runners

You are invited to participate in a research study that will investigate whether a progressive running training intervention changes how you run. We will investigate this question by having you complete a baseline running test, a running training program, daily running logs, and a post-training running test. The running training includes a typical week of running for you plus 12 weeks of progressively increasing your mileage (13 weeks total).

You were selected as a possible participant in this study because you began running at least 3 months ago, are 18-40 years old, can run for 20 minutes continuously, run an average of 3-20 miles per week, and have been running at least 3 miles per week during the last 3 months. Please read this form and ask any questions you may have before agreeing to be in the study.

The study is being conducted by Dr. Allison Gruber from the Biomechanics Laboratory within the Department of Kinesiology, Indiana University Bloomington.

STUDY PURPOSE

The purpose of this study is: 1) to determine if how you run changes after a prolonged treadmill run; 2) to determine if changes in how you run can be observed following the first 4-weeks of a 13-week progressive running training program; and 3) and to determine if changes in how you run can be observed at the end of the 13-week progressive running training program. Essentially, we are examining how your running form changes over the course of a 13-week running training program that progressively increases your weekly running mileage.

NUMBER OF PEOPLE TAKING PART IN THE STUDY:

If you agree to participate, you were one of up to 100 participants who were included in this research study.

PROCEDURES FOR THE STUDY:

If you agree to be in the study, you will do the following things:

We will ask you to complete a modified physical activity questionnaire to assess your health history. If deemed qualified to participate, you will then complete a Mood State Questionnaire and a questionnaire asking you about your running training and injury

history. We will then discuss your individualized 13-week progressive training program and show you how to use the Fitbit Inspire, which were worn whenever you are awake, and an activity monitor, which were worn during all of your runs. The Fitbit and activity monitor will track your running mileage and physical activity throughout the 13-week training program. We will then schedule a time for you to come back to the laboratory and complete the three running form analyses. Completing the consent procedures, the questionnaires, reviewing your running training program, providing you with instruction for the Fitbit and activity monitor, and scheduling your running form analyses will take approximately 30-45 min.

You were asked to wear the wrist-worn Fitbit and the hip-worn Actigraph devices provided during all of your runs throughout the 13-week training program. You were asked to run your typical weekly mileage for the first week of the training program, then increase your weekly running mileage for three, 4-week periodized cycles. For each cycle, weekly mileage were increased by 15% during the loading weeks while the recovery week (i.e., 4th week) were reduced by 20% relative to the prior week. The training plan were developed based on how many runs you perform per week. You were given your program at the start of the study, but how many runs you perform each week and for how many miles may be adjusted week to week, depending on the information you provide us in the running log.

We need you to complete the total number of miles per week that is prescribed, to the best of your ability. We can adjust the program after it is started to better accommodate your schedule, so you are able to complete the prescribed weekly mileage. Please contact us at the beginning of a week if you feel as though adjustments to your training plan need to be made!

Below is an example of a plan for someone who runs 20 miles in 4-5 runs per week:

	Week	Lab Visits	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
Typical week			3	3	0	3	4	0	7	20.0
Rest week	0	Enrollment	3	3	0	3	3	0	4	16.0
Normal mileage	1	Gait Analysis 1	3	3	0	3	4	0	7	20.0
Cycle 1 Load	2		4	4	0	3	4	0	8	23.0
Cycle 1 Load	3		4	5	0	4	4.5	0	9	26.5
Cycle 1 Load	4		4	5	2	4.5	5	0	10	30.5
Cycle 1 Deload	5	Gait Analysis 2	4	5	0	4	4.5	0	7	24.5
Cycle 2 Load	6		4	5	0	4	4	0	11	28.0
Cycle 2 Load	7		4	5	3	5	4	0	11	32.0
Cycle 2 Load	8		5	6	3.5	5	5	0	12	36.5
Cycle 2 Deload	9		4	5	0	4	5	0	11	29.0
Cycle 3 Load	10		5	5	2	4	5	0	12	33.0
Cycle 3 Load	11		6	6	2	5	7	0	12	38.0
Cycle 3 Load	12		6	7	5	6	7	0	13	44.0

Cycle 3 Deload	13	Gait Analysis 3	5	6	3	6	6	0	10	36.0
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You were asked to record your running and other exercise in an online log. A link to the log were emailed to you every morning. We ask that you enter the details of your running and other exercise in this log daily. The log will also have a section for you to record your ratings of perceived fatigue (0 to 10 scale; 0 = no fatigue at all; 10 = most fatigue imaginable) and reports of pain or injury. Each log will take less than 5 minutes to complete. At the very beginning and very end of each of the three recovery weeks, you will also receive a link to complete a Mood State questionnaire. This were identical to the one that you will complete today, but asking you to answer each question regarding how you feel at that moment.

The first in-lab analysis of your running form will involve you first changing into clothes provided by the laboratory and the running shoes you normally wear. You were asked to mark how much overall body fatigue and leg fatigue you feel right now on a visual analog scale (0 = no fatigue at all; 10 = most fatigue imaginable). You will also be asked to complete a survey that will help us measure your feelings of fatigue and your feelings of energy at that particular time.

Next, you will kick a soccer ball three times to establish which foot is your dominant foot.

We will then place reflective markers on your legs, hips, and shoes to help us measure how your body moves during running. We will also attach accelerometer sensors to your right lower leg, your lower back, and your forehead to study the movements of these body segments. Your activity monitor were secured around your waist, like a belt, with the device centered on your lower back. We will also ask you to wear a chest-worn heart rate monitor.

We will then have you run across the floor and on a treadmill in the Biomechanics Laboratory at your preferred training pace—that which is typical during a 20-40 minute run. Thirteen motion capture cameras will capture the position of the markers as you run through the collection space (approximately 16 m or 52 ft long) and on the treadmill. The motion capture cameras cannot record any information except for the position of the markers. Therefore, you cannot be personally identified by these recordings. The data collection space also has three force platforms in line with one another that are located in the floor at the center of the data collection space. These force platforms are like fancy scales and will measure the forces you apply to the ground when you run. You were asked to conduct two vertical jumps atop the force plates; this activity will help us measure your body’s readiness to perform physical activity. The “readiness” is like your body’s feelings of energy or fatigue and may differ from how you personally feel. You will then run through the data collection space at your typical, preferred running speed. You were asked to complete at least 10 trials of the short run. You may be asked to complete more than 10 trials if any of the trials do not result in successful recording of the markers, acceleration, or force platform data.

You will then be asked to run on the treadmill at your preferred running speed. You will run on the treadmill for the same amount of time you typically perform (by either miles or time) or until you tell us you can no longer continue (whichever happens first). During the treadmill run, you were asked how much effort you are expending on a scale from 6 to 20 (6 = no exertion at all; 20 = maximal exertion). This scale is called the Borg Rating of Perceived Exertion (RPE) scale. We will ask you to rate your perceived exertion every five minutes while you are running on the treadmill. Immediately after you have completed the treadmill run, we will ask you to rate your overall body fatigue and your lower body fatigue again on the visual analog scale. As soon as possible after the treadmill run is completed, you will perform two more vertical jumps, then ten additional over-ground running analyses (same procedures as described above). It is important that we measure your jump and running form as soon as possible after the treadmill run has ended so we can measure the effect that the treadmill run had on your form.

After the running form analysis is complete, we will ask you to perform two final vertical jumps atop the force plates. The markers, accelerometers, and belt-mounted devices will then be removed, and lab clothing returned. We will then confirm when you will start the running training program (the Monday of the next week), confirm your appointment days for the second and third running form analyses, and answer any remaining questions about the Fitbit, Actigraph activity monitor, or online log. The running form analysis will take approximately 60-120 min. If your data collection cannot be completed as described above for any reason (e.g., fire drill, equipment malfunction) you may be asked to return to the lab to repeat the data collection. You will only be asked to repeat the data collection if the new appointment occurs at the end of weeks 4, 8, or 12 or at the beginning of weeks 5, 9, or 13.

You will return to the lab after completing week 4 of the training program and after completing week 12 of the training program to complete the second and third running form analyses. Both of these running form analyses will have the same procedures described above. **It is extremely important that you return to the lab to complete running form analysis as soon as possible after week 4 and week 12 have ended** (which were during weeks 5 and 13). You will return the activity monitor and be gifted your Fitbit at the completion of the study. Each of the running form analyses will take approximately 60-120 min. Therefore, your participation in the lab for these three data collections and including today's visit to the lab (to complete the informed consent, questionnaires, and instructions) were 3.5 – 7 hours.

We ask that you do not make any other changes to your running program while you are enrolled in the study except for the mileage that we prescribe for you. For example, please do not add a new workout routine, switch brand/model of your running shoe, change running surface, etc.). Please inform the research staff today if you plan to participate in any races or if/ when you expect to replace your running shoes in the next 13 weeks. Please inform a member of the research staff if you make any other changes to your normal, daily routine. These changes may not disqualify you from the study, we simply need to know of any changes that may impact the results.

Sometime after you complete week 13 of the training plan, we will ask you to return to the lab to complete a shorter version of the running form analysis. This shorter version of the running form analysis were identical to the procedures described above except 1) the reflective markers will only be placed on your pelvis and your right limb; 2) the triaxial accelerometers and physical activity monitor will not be worn; 3) the treadmill run will only last for 7 minutes; and 4) no additional surveys or monitoring were required outside of the lab. The purpose of this fourth running form analysis is to determine if the overground running form you perform after the treadmill run is due to the duration of the treadmill run or due to transitioning from a treadmill run to an overground run. It is important that you are as physically rested as possible before you complete this final data collection. Therefore, it is important to schedule the data collection so that: 1) no long, difficult, or intense runs or exercise are performed the day or week before (depending on the distance or duration of prior activity); 2) you have not experienced pain or injury within the last 8 weeks; or 3) if you experienced an injury since completing the study, you have returned to your normal weekly mileage for at least 6 weeks. It is expected that this fourth running form analysis will take 1 hour. Therefore, your total participation in the lab were 4.5 – 8 hours. If your data collection cannot be completed as described above for any reason (e.g., fire drill, equipment malfunction) you may be asked to return to the lab to repeat the data collection. The timing of this repeated data collection is not important to the procedures of the study and so it can happen at any time that is convenient for you.

RISKS OF TAKING PART IN THE STUDY:

While participating in this study, the risks are:

- Muscle soreness or fatigue
- Development of a running related overuse injury
- Possible discomfort from the adhesive and wraps used to secure the reflective markers
- Possible loss of confidentiality

During the testing protocol, there is minimal risk that you may experience fatigue or muscle soreness due to performing the running form analysis. The risk of fatigue and muscle soreness were decreased by allowing you to self-select your running speed, and the run you perform in the lab is the same as the longest run you perform. You will likely consider the intensity of the running form analysis to be no different than the runs you perform outside the lab. Therefore, the risk of muscle soreness or fatigue is further minimized.

There is a risk that you will experience a running injury while enrolled in the study. The purpose of the study is to examine how your running form changes over the course of a typical running training program. Each 4-week cycle has you increase your mileage for 3 weeks followed by 1 week of “recovery” (i.e., reduced mileage). This program was chosen to significantly increase your running mileage without being overly aggressive or

increasing the risk of developing an injury. The increase in mileage we will prescribe for you is similar to a program you would follow if you were training for a distance race, such as a 10K or marathon.

You may develop skin irritation and/ or a slight rash due to the application and removal of the reflective markers and accelerometers. Please let the researchers know if your skin is sensitive, or if you experience skin discomfort. If necessary, there are sterile alcohol pads available in the laboratory to provide temporary skin relief. Any potential discomfort would be no greater than wearing a Band-Aid.

There also may be other side effects that we cannot predict. There is also a small possibility of loss of confidentiality. The likelihood of loss of confidentiality is very low because only members of the research staff were in the lab when you are being tested and see your data. We also have a system to prevent anyone outside of the research staff from identifying you with your data. All questionnaires and data were coded by your subject number only.

BENEFITS OF TAKING PART IN THE STUDY

There are no direct benefits to taking part in this study. However, by taking part in this study, you were contributing to the knowledge of the field to help us better understand how fatigue affects running gait complexity.

CONFIDENTIALITY

Efforts were made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Your identity was held in confidence in reports in which the study may be published. Data were recorded with numerical identifiers, were stored securely on a laboratory computer, and were made available only to people involved with the study unless you specifically give permission in writing to do otherwise. No reference were made in verbal or written reports which could link you to this study.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Indiana University Institutional Review Board or its designees, and (as allowed by law) state or federal agencies, specifically the Office for Human Research Protections (OHRP), who may need to access your research records.

FUTURE USE OF INFORMATION

Information collected for this study may be used for future research studies or shared with other researchers for future research. If this happens, information which could identify you were removed before any information or specimens are shared. Since identifying information were removed, we will not ask for your additional consent.

COSTS

There are no costs associated with participation in this study. However, the equipment you were using is the property of Indiana University and **must be returned at the end of the study**. This equipment includes the Fitbit (~\$100), activity monitor (~\$230), and the activity monitor's belt, charging cord and charging block (~\$35). You were charged if the equipment is lost, damaged, or not returned when your enrollment ends. The approximate cost of the equipment you were using totals at least \$365.

PAYMENT

Upon completion of the 13 weeks and after the equipment provided is returned to lab personnel, you were permitted to keep the Fitbit Inspire (a \$100 value) that you'll have used throughout the protocol and will receive a detailed running analysis report (a \$200+ value). If you are not able or willing to complete the 13-week training program, you must contact a member of the research staff to declare your withdrawal in writing and return all of the equipment, to include the Fitbit. You will still receive the running analysis report after the equipment is returned.

COMPENSATION FOR INJURY

In the event of physical injury resulting from your participation in this research when you are in the lab, lab personnel will assist you in obtaining any necessary medical treatment which were billed as part of your medical expenses. If you experience an injury outside of the lab as part of your running training, seek medical treatment as you normally would, using your best judgment. Any medical treatment and costs not covered by your health care insurer were your responsibility. Also, it is your responsibility to determine the extent of your health care coverage. There is no program in place for other monetary compensation for such injuries. However, you are not giving up any legal rights or benefits to which you are otherwise entitled. If you are participating in research which is not conducted at a medical facility, you were responsible for seeking medical care and for the expenses associated with any care received.

CONTACTS FOR QUESTIONS OR PROBLEMS

For questions about the study or a research-related injury, contact the researcher Dr. Allison Gruber at ahgruber@indiana.edu.

In the event of an emergency, you may contact Allison Gruber at (978) 697-2631. If the emergency is medical in nature, call 911 and contact Allison Gruber after the emergency has passed.

For questions about your rights as a research participant or to discuss problems, complaints, or concerns about a research study, or to obtain information, or offer input,

contact the IU Human Subjects Office at (317) 278-3458 or [for Indianapolis] or (812) 856-4242 [for Bloomington] or (800) 696-2949.

VOLUNTARY NATURE OF STUDY

Taking part in this study is voluntary. You may choose not to take part or leave the study at any time. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. Your decision whether to participate in this study will not affect your current or future relations with the investigators or Indiana University. We ask that you contact a member of the research team if you wish to withdraw from the study.

Your participation may be terminated by the investigator without regard to your consent in the following circumstances: We observe that you are not regularly completing the prescribed running training, running log, wearing the foot pod and/or activity monitor, or you are unable to perform the tasks we have described in this document.

For the duration of this study (13 weeks), participation in this study will preclude you from participating in other exercise-based research studies that would cause you to change your weekly running mileage/deviate from your prescribed progressive running training program.

SUBJECT'S CONSENT

In consideration of all of the above, I give my consent to participate in this research study. I was given a copy of this informed consent document to keep for my records. I agree to take part in this study.

Subject's Printed Name: _____

Subject's Signature: _____ **Date:** _____
(must be dated by the subject)

Printed Name of Person Obtaining Consent: _____

Signature of Person Obtaining Consent: _____ **Date:** _____

PARTICIPANT CONTACT INFORMATION

Cell phone number: _____

Living Address: _____ Permanent Address: _____

Appendix B: Modified Physical Activity Readiness Questionnaire & Health

History

The American College of Sports Medicine Exercise Preparticipation Health Screening

Please answer the following questions to the best of your knowledge (circle YES or NO)

1. YES NO Do you participate in regular exercise?
2. YES NO Have you ever been diagnosed with a heart condition, cardiovascular disease (e.g. high blood pressure (hypertension), coronary heart disease, coronary artery disease, high cholesterol), metabolic disease (e.g. Type I or Type II diabetes), renal disease, or pulmonary disease (excluding regular asthma)?

YES NO 2a. If yes, have you experienced any of the following in the past 12 months: chest pain, shortness of breath, pain or numbness in the arms or legs, fainting, swelling of the ankles, abnormally quick heartbeat, cramping in the leg, or pain in the neck, back, or upper abdomen?

YES NO 2b. If you answered yes to the above question (2a), has a doctor cleared you to continue with regular exercise including vigorous intensity exercise?

3. YES NO Has a doctor ever said that you should only perform medically supervised physical activity?
4. YES NO In the past month, have you developed chest pain when you are not performing any physical activity?

YES NO 4a. If yes, has a doctor told you it is okay to continue exercise including vigorous intensity exercise? Please provide reasoning:

5. YES NO Do you ever feel faint, pass out, or have spells of severe dizziness, palpitations, or excessively rapid heartbeat at rest or during exercise?

YES NO 5a. If yes, has a doctor told you it is okay to continue exercise including vigorous intensity exercise? Please provide reasoning:

6. YES NO Have you ever been diagnosed with a neurological problem (e.g. stroke, MS, ALS, neuropathy, etc.)?

7. YES NO Have you injured bones, joints, or muscles in your back or legs in the last 3 months?

YES NO 7a. If yes, have you returned to your normal running training and mileage?

7b. If yes to question 7a above, how long have been performing your normal running training and mileage?: _____

8. YES NO Have you ever had any surgery to your legs or back?

9. YES NO Is there any reason not mentioned above why you should not engage in physical activity including vigorous intensity exercise? If yes, please explain:

Appendix C: Profile of Mood States Questionnaire

Instructions

In the following questionnaire you will find a list of words that describe feelings people have. Please read each one carefully, then select one phrase/ word which best describes how you have felt during the past week, including today.

	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Friendly	0	0	0	0	0
Tense	0	0	0	0	0
Angry	0	0	0	0	0
Worn Out	0	0	0	0	0
Unhappy	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Clear-headed	0	0	0	0	0
Lively	0	0	0	0	0
Confused	0	0	0	0	0
Sorry for things done	0	0	0	0	0
Shaky	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Listless	0	0	0	0	0
Peeved	0	0	0	0	0
Considerate	0	0	0	0	0
Sad	0	0	0	0	0
Active	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
On edge	0	0	0	0	0
Grouchy	0	0	0	0	0
Blue	0	0	0	0	0
Energetic	0	0	0	0	0
Panicky	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Hopeless	0	0	0	0	0
Relaxed	0	0	0	0	0
Unworthy	0	0	0	0	0
Spiteful	0	0	0	0	0
Sympathetic	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Uneasy	0	0	0	0	0
Restless	0	0	0	0	0
Unable to concentrate	0	0	0	0	0
Fatigued	0	0	0	0	0

Helpful	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Annoyed	0	0	0	0	0
Discouraged	0	0	0	0	0
Resentful	0	0	0	0	0
Nervous	0	0	0	0	0
Lonely	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Miserable	0	0	0	0	0
Muddled	0	0	0	0	0
Cheerful	0	0	0	0	0
Bitter	0	0	0	0	0
Exhausted	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Anxious	0	0	0	0	0
Ready to fight	0	0	0	0	0
Good natured	0	0	0	0	0
Gloomy	0	0	0	0	0
Desperate	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Sluggish	0	0	0	0	0
Rebellious	0	0	0	0	0
Helpless	0	0	0	0	0
Weary	0	0	0	0	0
Bewildered	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Alert	0	0	0	0	0
Deceived	0	0	0	0	0
Furious	0	0	0	0	0
Efficient	0	0	0	0	0
Trusting	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Full of pep	0	0	0	0	0
Bad-tempered	0	0	0	0	0
Worthless	0	0	0	0	0
Forgetful	0	0	0	0	0
Carefree	0	0	0	0	0
	0; Not at all	1; A little	2; Moderately	3; Quite a bit	4; Extremely
Terrified	0	0	0	0	0
Guilty	0	0	0	0	0
Vigorous	0	0	0	0	0
Uncertain about things	0	0	0	0	0
Bushed	0	0	0	0	0

Appendix D: Running Training and Injury History – Recreational Runners

Instructions: In the following survey, you were asked questions about your current running training, running training history, any non-running physical activity that you preform, about your shoe and orthotic preferences, and about any orthopedic injuries that you have sustained. Please be as accurate and detailed as possible in your responses - the more accurate and detailed your responses, the better we were able to identify the causes of running-related injuries.

Running Training History

- 1) How long have you been running more than 10 miles per week consistently?
- 2) What has been your average miles per week over that time?
- 3) Have your miles per week been about the same for as long as you have been running or has it varied?
 - My weekly mileage has varied over the time that I have been running.
 - My weekly mileage has been about the same for the time that I have been running.
- 4) Why did you start running?
 - To train for a race.
 - For general health/fitness purposes.
 - To be part of a group/the social aspect.
 - Other. Please explain: _____
- 5) What type of runner do you consider yourself?

Health/fitness	Recreational	Competitive	Other
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Current Training – The following questions refer to the training you have done in last 3 months or the most recent change to your running habits within that time.

- 6) What has your average weekly running mileage been for the last 3 months?
- 7) What is the typical distance you complete for each run?
- 8) How many runs do you perform each week?
- 9) Borg Rating of Perceived Exertion for typical run? (circle a number below)

6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

- 6 = no exertion at all
- 7.5 = extremely light
- 9 = very light. For a healthy person, it is like walking slowly at his/her own pace for some minutes
- 11 = light
- 13 = somewhat hard, but it still feels ok to continue.
- 15 = hard (heavy)

- 17 = very hard. A healthy person can still go on, but he/she really has to push themselves. It feels very heavy, and the person is very tired.
- 19 = extremely hard. For most people this is the most strenuous exercise they have ever experienced.
- 20 = maximal exertion

10) How many hours per week do you currently run?

11) How many months out of the year do you typically run?

12) What is your usual running pace or running speed for an 'easy run'?

Pace (min-mile)	Speed (mph)

13) What surfaces do you usually run on? For each surface, please tell us the time and/or the number of miles per week you run on this surface.

Surface	No. of runs per week	Time (in minutes)	Distance (in miles)
Pavement			
Dirt path/trail			
Track			
Grass			
Treadmill			
Other			

14) Do you typically complete a 'long' run each week? YES NO

[If yes, proceed to question 15]

[If no, skip to question 16]

15) How long is your 'long' run?

16) Do you usually perform any special running training (such as sprinting, intervals, hills, tempo, etc.)?

Yes

No

[If yes, proceed to question 17]

[If no, skip to question 18]

17) Please tell us about the special running training that you perform by completing the following table.

In the row listed as "other", please enter any other activities that you regularly participate in that were not listed previously in this table. Please tell us what activity that is in the "Additional Info" column.

	Do you perform?	Estimated total time per bout	No times per week	No weeks per month	No months per year	Perceived Intensity	Surface	Additional info to share
Fartlek's (typical interval type)	YES/NO					Light, moderate, vigorous		
Sprint/track-interval workout								
Tempo runs								
Hill repeats								
Stair repeats								
Other								

18) In the space provided below, please provide any additional information that you would like us to know about your current running training.

Running Shoes and Orthotics

1) Do you wear your running shoes for all other types of physical activity or exercise? Or do you have different shoes for running than your wear for other forms of physical activity or exercise?

- I wear my running shoes for running only
- I use the same pair of shoes for all types of physical activity or exercise
- I run barefoot
- Other. Please explain:

2) Do you run in a single pair of shoes or alternate between shoes?

- Single pair
- I Switch between two or more pairs throughout the week
- I switch between barefoot running and running with shoes.
- I run barefoot for all of my runs, regardless of speed, distance, surface, or etc.
- Other. Please explain:

[if item 4, please skip to question 10]

3) What type of shoe(s) do you wear for running and for what running purpose (e.g. general, road, trail, race, etc.)?

	Brand	Model	Style (e.g. motion control, etc.)	male/female sizing	Size	Primary use (running, trail running, non-running exercise, other)
Shoe 1						
Shoe 2						
Shoe 3						
Shoe 4						
Shoe 5						

4) How often do you replace your running shoes? Please report in months and/or miles.

Months	Miles

5) Do you wear orthotics, shoe inserts, or arch supports?

- Yes No I used to, but do not now

[If yes or 'used to', proceed to question 6]

[if no, skip to question 10]

6) Do/did you wear your orthotics all the time or only during certain activities?

- I wear my orthotics all the time.
 I wear my orthotics when I run only.
 I wear my orthotics when I perform any physical activity or exercise.
 I wear my orthotics for exercise if I remember.
 I have orthotics, but I usually don't wear them.

7) Were your orthotics recommended or prescribed by a doctor?

- Yes, my doctor prescribed (required) me to wear orthotics.
 Yes, my doctor recommended or suggested that I wear orthotics but it was up to me.
 No, I decided to wear orthotics on my own.

8) Were your orthotics custom made or store bought?

- Custom made by my doctor.
 Semi-custom orthotics determined by the Dr. Scholls FootMapping® System or similar
 Off the shelf

9) What are your orthotics designed to do or treat? Please check all that apply.

- I'm not sure
- increase cushioning
- alignment
- Arch support
- over pronation
- over supinating
- rearfoot control
- other. Please describe:

10) In the space provided below, please provide any additional information that you would like us to know about your running shoe preferences:

Other Activity

1) Have you regularly participated in any exercise or physical activity at least 10 or more times in the past year, besides running?

- Yes, other types of exercise in addition to running for all of the past year
- Yes, other types of exercise in addition to running for only all or part of the last three months
- Yes, I did do other activity but I have not done it within the past three months.
- No, only running

[If yes, proceed to question 2]

[if no, skip to question 3]

2) In the past 12 months, have you participated in any of the following activities 10 or more times? If yes, please check the box next to each activity. Then, please tell us which months out of the year you participated in the activity, the average number of days per week you participated, and the average number of hours per week that you participated in the activity:

*****See attached list of activities on the next page*****

In the past 12 months, have you participated in any of the following activities 10 or more times? If yes, please check the box next to each activity. Then, please tell us which months out of the year you participated in the activity, the average number of days per week you participated, and the average number of hours per week that you participated in the activity:

	Have you participated in these activities within the past 12 months?		Months of that you participate in activity												Ave days per week of activity	Ave hours per week of activity	Additional info to share with us
	Yes	No	Jan 1	Feb 2	Mar 3	Apr 4	May 5	Jun 6	Jul 7	Aug 8	Sep 9	Oct 10	Nov 11	Dec 12	(# of days/wk)	(# of hrs/wk)	Yes
Aerobics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Band/Drill Team	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Baseball	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Basketball	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Bicycling	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Bowling	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Cheerleading	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Dance Class	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Elliptical	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Football	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Garden/Yard Work	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Gymnastics	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
High Intensity Interval Training	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Hiking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Heavy Household	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Ice Skating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Pilates or Barre	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Roller Skating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Running for Exercise	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Skateboarding	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Snow Skiing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Soccer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Softball	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Stair master or climbing machine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Exercise	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Water Skiing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Weight Training	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Wrestling (competitive)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Yoga	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Other, field sports	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Other, stationary aerobic machines	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Other, aerobics classes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Other, not listed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			

- 3) In the space provided below, please provide any additional information that you would like us to know about your other usual forms of physical activities or exercise.

Orthopedic and Running Injury History

- 1) Have you ever experienced pain or injury to your hips, legs, ankles, knees, feet, toes, or back due to exercise and/or running? These can be either acute/happened all of a sudden or chronic injuries caused by running or other exercise or physical activity.

Some examples of acute/traumatic/happened all of the sudden injuries are: rolling your ankle, falling, breaking a bone, getting hit, all of the sudden muscle pull or tear of a tendon, muscle, or ligament, or *injury resulting from a fall/trip/getting hit*.

Some examples of chronic/overuse injuries are: tendinitis, IT-band syndrome, runner’s knee, stress fractures, or plantar fasciitis.

- Yes No

[If yes, proceed to question 2]

[if no, skip to question 3]

- 2) Please describe all of the you have experienced due to running or other exercise by entering in the following information for each injury.

For the "Additional information to share with us" row, please tell us more about the injury if you wish. For example, how it happened, how long it affected you, if it bothered you only when you were running, etc.

Some examples of acute/traumatic/happened all of a sudden injuries are: rolling your ankle, falling, breaking a bone, getting hit, all of a sudden muscle pull or tear of a tendon, muscle, or ligament, or injury resulting from a fall/trip/getting hit. Some examples of chronic/overuse injuries are: tendinitis, IT-band syndrome, runner’s knee, stress fractures, or plantar fasciitis.

Injury number	1	2	3	4	5
Location (body part)					
Side of the body (R or L)					
Diagnosis or injury description					
How long ago (months)					
Pain Level: 0 (no pain) - 10 (horrible pain)					
Did it affect your running training? (reduce, stop, or no change)					
Seek Medical treatment? (yes or no)					
Was it caused by running specifically? (yes or no)					
Acute or chronic?					

Additional info to share					
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- 3) Do you ever perform any modalities such as foam rolling, massage, ice, heat, stim/tens, etc. on your own? That is, modalities you perform yourself, not part of a visit to a clinician?
- Yes, on my own (i.e. at home) as instructed by a clinician
 - Yes, on my own (i.e. at home) but I was not instructed to do so by a clinician
 - No

[If yes, proceed to question 4]

[if no, skip to question 5]

- 4) How often do you perform the following modalities?

	Every day as part of my normal routine	Most days of the week as part of my normal routine	Sometimes as part of my normal routine	Only before or after running or exercise	Only if I have pain/injury	Never
Foam Rolling						
Massage						
Ice						
Heat						
Chiropractor						
Muscle Stim						
Stretching with or without bands						
Strengthening with bands						
Other						

- 5) In the space provided below, please provide any additional information that you would like us to know about your running injury history?

Appendix E: Daily Running Log

Week	Out of Lab	In Lab	Training							Total
1	Normal Mileage	Gait Analysis 1	Mon	Tues	Wed	Thurs	Fri	Sat	Sun	Total
2	Cycle 1 Load									
3	Cycle 1 Load									
4	Cycle 1 Load									
5	Cycle 1 Deload	Gait Analysis 2								
6	Cycle 2 Load									
7	Cycle 2 Load									
8	Cycle 2 Load									
9	Cycle 2 Deload									
10	Cycle 3 Load									
11	Cycle 3 Load									
12	Cycle 3 Load									
13	Cycle 3 Deload	Gait Analysis 3								

All distances/ durations are in kilometers/ miles/ minutes.

Appendix F: Daily Running & Activity Survey

Subject ID Please enter your subject ID.

Q1 Did you run today?

- Yes | *proceed to question 2*
- No, scheduled day off from running | *proceed to Question 4*
- No, unplanned day off from running | *proceed to Question 5*

Q2 Please complete the following information about today's run:

Time to completion (in minutes):

Distance (in miles):





Surface (select one): pavement, dirt path or trail, track, grass, other

Perceived intensity (select one): light, moderate, vigorous

Additional information to share: optional

Q3 Please rate your overall body fatigue and your lower body fatigue **before and after your run** today from 0 (no fatigue at all) to 10 (most fatigue imaginable):

0 1 2 3 4 5 6 7 8 9 10

LOWER body fatigue BEFORE your run ()	
OVERALL body fatigue BEFORE your run ()	
LOWER body fatigue AFTER your run ()	
OVERALL body fatigue AFTER your run ()	

Proceed to Question 7 if Question 3 is completed

Q4 Please rate the overall body fatigue and the lower body fatigue that you felt **today overall** from 0 (no fatigue at all) to 10 (most fatigue imaginable):



0 1 2 3 4 5 6 7 8 9 10

LOWER body fatigue today ()	
OVERALL body fatigue today ()	

Proceed to Question 7 if Question 4 is completed

Q5 Please rate the overall body fatigue and the lower body fatigue that you felt **today overall** from 0 (no fatigue at all) to 10 (most fatigue imaginable):

0 1 2 3 4 5 6 7 8 9 10

LOWER body fatigue today ()	
OVERALL body fatigue today ()	

Q6 Why did you not run today?

- Pain, injury, or illness
- Did not have time
- Forgot
- Other, please specify:

Q7 Did you perform any other exercise of physical activity?

- Yes | *proceed to Question 7B*
- No | *proceed to Question 8*

Q7B Please tell us about the other exercise or activity that you did today.

Non-Running Exercise (select one): cycling, swimming, weightlifting, yoga/ Pilates/ stretching/ Barre, walking, Bootcamp, HIIT, other group class, other aerobic or endurance, other non-aerobic, core strengthening

Time (minutes):

Distance (in miles; if applicable):

Perceived intensity (select one): light, moderate, vigorous

Q8 Did you experience any illness today?

Yes or No

Q9 Did you experience any pain or injury today?

- Yes, it started today | proceed to Question 10
- Yes, it started on a previous day (new problem I have not reported yet) | proceed to Question 10
- Yes, it started on a previous day (previous problem, I have already reported it) | proceed to Question 14
- No | proceed to Question 15

Q10 Did the pain, injury, or illness affect your run today?

- No, today was a planned day off from running
- No, I ran without restrictions
- I ran at a reduced intensity or distance for LESS than half of today's run
- I ran at a reduced intensity or distance for MORE than half of today's run
- I did not run but I preformed some other form of exercise WITHOUT pain
- I did not run but I preformed some other form of exercise WITH pain
- I did not run or preform some other form of exercise because of pain or illness

Q11 Was the pain or injury caused by running?

- Yes, today's run
- Yes, running on a previous day
- No, but it started today
- No, but it started on a previous day

Q12 Please tell us about the pain or injury you felt today:

Location (select one): back, pelvis, hips, thigh, knee, lower-leg/ calf, ankle, foot/ toes

Side of the body (select one): right, left

Is it acute or chronic: acute/ traumatic/ all of the sudden, chronic/ overuse

Pain level (0-10; select one): 0 (no pain), 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 (most pain imaginable)

Q13 Please describe the injury and tell us what happened (when it occurred, how it was caused, diagnosis or name of the problem, etc.).

Q14 Did you seek new medical treatment for the pain or injury you are reporting today?

*Click no if you have sought medical treatment for this pain or injury in the past **but not for this specific instance.***

Yes

No

Q15 Please use the space below to tell us any additional information you would like to share. If you do not have any additional info to share, click "next" to submit your log.

If you are completing this log for a day other than today, use this space to enter the date for which this survey applies.

Use the space below to tell us anything we need to know that might affect your data. **For example: if you were unable to wear the ActiGraph during your run or forgot to wear it, if you are having trouble completing the training program as prescribed, etc.**

Q16 Thank you for your continued participation in the study! If you have any questions, please contact Katie Davel (kadavel@iu.edu).

Author's CV

Captain Kathryn A. Davel

kathryndavel@gmail.com (primary); kathryn.a.davel.mil@army.mil (alternate)

CURRENT ADDRESS

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Ellettsville, IN 47429
(260) 704-2140

EDUCATION

Indiana University	Bloomington, IN
<i>Master of Science in Kinesiology (Biomechanics)</i>	May 2023
Cumulative GPA: TBD	
Missouri University of Science and Technology	Rolla, MO
<i>Master of Science in Engineering Management</i>	May 2018
Cumulative GPA: 3.70	
United States Military Academy	West Point, NY
<i>Bachelor of Science in Kinesiology</i>	May 2013
Cumulative GPA: 3.26	

PROFESSIONAL EXPERIENCE

Indiana University School of Public Health	Bloomington, IN
<i>Graduate Student, Advisor: Allison Gruber, PhD</i>	May 2023

- Completed curriculum focused in factors affecting human performance with an emphasis on biomechanics.
- Conducted research focused in running-related injury prevention and wearable device-guided interventions.
- Received the 2022-2023 Marjorie P. Phillips Fellowship

United States Army	Fort Leonard Wood, Missouri
<i>Captain, Engineer Officer</i>	May 2013 – Present

- Selected to instruct Engineer Captain's Career Course at the Maneuver Support Center of Excellence; earned Army Basic Instructor Badge.
- Served as Operations Officer for the Engineer Regiment's Department of Instruction; responsible for the budgets, programs of instruction, scheduling, and knowledge management of the Regiment's Officer and Warrant Officer courses, to include two Pre-Command Courses which prepare selectees to lead formations of over 1,000 personnel.
- Commanded a One Station Unit Training (OSUT) company responsible for training 1,100 combat engineers and bridge-crewmembers annually and a headquarters company; led the implementation of

the Army Combat Fitness Test (ACFT) and COVID-19 prevention measures in Soldiers' initial entry training.

- Served as Training Officer for the Department of Military Engineering in the Regiment's only training brigade; responsible for the curriculum, automation, budget, and accreditation supporting an annual load of 14,000 students.
- Served as Executive Officer of the US Army Pacific Command's only Engineer Construction Company; responsible for planning, resourcing, and managing projects on the Island of Oahu valued in excess of 5 million dollars.
- Deployed platoon to the Republic of Korea for 5 months in support of Task Force Ready as the first Echelon above Brigade (EAB) on the peninsula; trained the Republic of Korea Army on threat ordinance and mine detection.
- Led a Route Clearance platoon stationed in Schofield Barracks, HI for 15 months; prepared Soldiers for Route Reconnaissance and Clearance and Air Assault missions.

RESEARCH EXPERIENCE & PRESENTATIONS

Gruber, A.H., Davel, K.A., Chien, K.W., McDonnell, J. (2023) Mechanisms of Running-Related Injuries: Changes in gait during a typical run. Running Forward Mini Symposium. University of Twente, Twente, NL, February 3, 2023.

SKILLS AND ACCOMPLISHMENTS

- *Software:* MATLAB, Excel, Qualisys Track Manager (QTM) Motion Capture, C-Motion Visual3D Analysis Tool
- *Technical Certifications:* Project Management Professional (PMP); Military Construction Management; Global Project Management; Social and Behavioral Investigators/ Research Support Personnel/ Research Monitors/ Ombudsperson; Revised Common Rule; Tactical Strength and Conditioning Facilitator (TSAC-F); Certified Army Instructor; graduate of US Army Engineer Captain's Career Course; Anti-terrorism Level 2; CPR, First Aid, & AED
- *Tactical & Leadership:* Former U.S. Army Company Commander; Graduate of Route Reconnaissance and Clearance Leadership Course; graduate of US Army Sapper Leader Course; Modern Army Combatives Level 1
- *Languages:* English (primary); Spanish (4 years of study)
- *Personal:* expert communicator; highly-organized; socially-astute; goal-oriented

PERSONAL INTERESTS

- Family time; travel; recreational running and hiking; weightlifting; crafting; reading
- Married 6-years (Jacob), three daughters (Aubrey-5, Delaney-5, Cecilia-2), dogs (Wesson, Remi)