Spring 2023

Mind Over Body: A Comparison of Psychobiological Versus Physiological Focused Distance Runners

Adam Laurence Beach
Bard College, ab4855@bard.edu

Mind Over Body: A Comparison of Psychobiological Versus Physiological Focused Distance Runners

Senior Project Submitted to

The Division of Science, Math, and Computing

of Bard College

by

Adam Beach

Annandale-on-Hudson, New York

May 2023

Acknowledgments

I would like to thank both Frank Scalzo and Kristin Lane for helping me as my senior project advisors. I would also like to thank the psychology department's of both Bard College and Columbia-Greene Community College for guiding me through my academic journey.

Table of Contents

Abstract

Previous research has shown that psychology can have significant effects on endurance performance. According to exercise physiologist Samuele Marcora all performance gains in endurance racing are due to a reduction of perceived effort at a given pace (Sherman, 2021). The proposed study will compare athletes focusing on reducing perceived effort at a given pace over a four month training period with athletes focused on improving physical fitness over the same period. The fitness group will complete workouts designed to maximize physiological indicators while the perceived effort groups will complete workouts designed to reduce perceived effort while running at a given pace. Participants will partake in a five-kilometer race before and after the four month training period. Expected results will include a greater increase in performance over the second race for the perceived effort group as well as less injuries in the perceived effort group.

Intro

The body and mind are interconnected, when the body pushes itself to an intense effort the mind indicates to slow down by causing pain; this phenomenon is called perceived effort. Samuele Marcora is an Italian exercise physiologist who was one of the first to study perceived effort in endurance exercise. He used the psychobiological model to explain the perception of how difficult an exercise feels. An athlete's ability to change “behavioral, emotional, and cognitive responses to discomfort and stress,” is their ability to cope with perceived effort and is malleable to training (Fitzgerald, 2015). The psychobiological model is a feedback loop that predicts that an increase in tolerance will occur either when the potential motivation is increased or when perceived effort is reduced. Perceived effort is defined by Marcora as “the conscious sensation of how hard, heavy, and strenuous a physical task is" (Blanchfield et al., 2014).

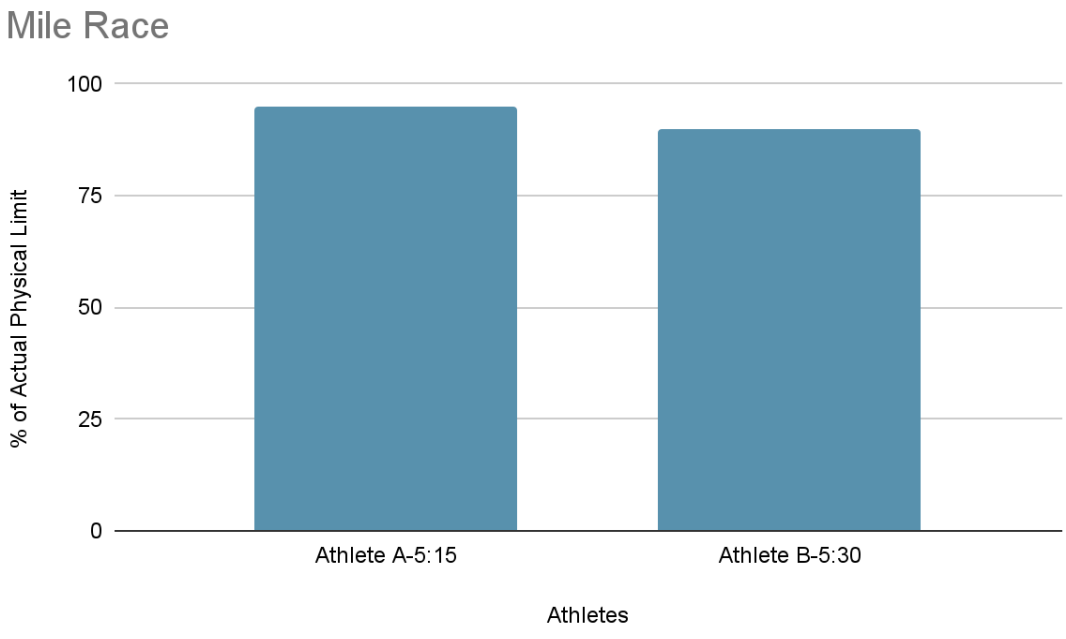
Perceived effort (henceforth PE) is experienced due to the corollary discharge which indicates that perceived effort is the brain’s awareness of the central motor’s commands when they are sent to the muscles that are being activated. Feedback from the muscles and other tissues may influence, but is not directly responsible for, the perceived effort. For example, directly after intense exercise athletes experience the delayed washout of metabolites, such as lactic acid, in muscle but they do not experience a high rating of perceived effort. If perceived effort was directly linked to physiological processes, the athletes in this example would continue to experience high PE despite having just stopped exercise (Smirmaul et al., 2013).

The sport of distance running is a very mentally demanding sport. Collegiate, high school, and professional athletes are asked to race 8+ times a season at 100% effort. Experienced distance runners are very experienced and comfortable with *race effort,* as any collegiate athlete

has been asked to race many times in their athletic career. Therefore, perceived effort is almost always constant for athletes at all races because they are always trying their hardest.

While PE is associated with physical exertion, the rate at which people experience perceived effort is individual and linked to a different percentage of actual physical limits (Fitzgerald, 2015). For example, two athletes who have identical physiologies, biologies, and fitness but have differing psychologies, will run different times in what they perceive as all out effort. One may run at 90% of their absolute physical limit while the other may run at 95% of their physical limit. While their physical fitness is still important, perceived effort can make the difference in a race. Figure 1.0 represents this example in a one mile race.

Figure 1. Both Athletes are physically capable of running a five minute mile. Athlete A runs 95% of the physical limit, resulting in a 5:15 mile time. Athlete B runs a 90% of physical limit resulting in 5:30 mile time.



Exhaustion can be defined as the disengagement from exercise when PE rises too high. Exhaustion can be warded off when an individual's motivation is higher. Training induced adaptations related to running tolerance will improve endurance performance indirectly by reducing PE (Smirmaul et al., 2013).

PE effects are evident when comparing athletes in open versus closed loop exertion. Open loop exertion is defined by a test where participants are instructed to perform until exhaustion. A closed loop test includes a known endpoint. During an open loop exertion test, athletes must make one simple decision- to stop or to continue. In open loop tests the psychobiological model explains why exercise intolerance can be manipulated by several external factors. These include music, verbal encouragement, and competition. In these scenarios an athlete's motivation rises and their willingness to give effort protects against an increase of perceived effort resulting in a better performance (Smirmaul et al., 2013).

Closed loop exercise tests are more common in real life scenarios. Any race distance, such as a 5k or marathon (42.2k), is closed loop exercise because the end point is known. In these tests athletes must make more complex decisions about pacing, based on prior experience and perception of effort (Smirmaul et al., 2013). For the purposes of the proposed study a closed-loop exercise test will be used, as it is more comparable to commonplace endurance racing and PE has been shown to have significant effects on this type of test before (Pageux et al. 2014).

Multiple studies have found evidence suggesting that endurance-based performance is limited by perceived effort. For example paralyzed people who control robot arms with impulses from their minds exhibit fatigue and after a period of time can no longer control the robot arms (Fitzgerald, 2015). In another study, by Wall et al., (2015), researchers dehydrated cyclists and

then tested their performance while manipulating the temperature at which the test took place. They concluded that dehydration does not have a significant effect on performance but feeling thoughts of thirst does. In this study the researchers concluded that at a certain degree dehydration does not have any negative physiological effects on performance but the feeling of thirst that participants experience will indicate to the brain that reducing effort is necessary. This is an example of the psychobiological model regulating exertion through perceived effort (Wall et al., 2015).

The mechanism as to why we feel pain during running is based on our body's energy pathway. The aerobic pathway provides energy through the use of oxygen, when using this energy pathway our perceived effort is low. Trained athletes can easily have full conversations while working at this effort level because they have more oxygen than is needed for the exertion. When exercising at higher intensities athletes will require energy at a faster rate than oxygen can deliver, at this point the anaerobic pathway is activated. The anaerobic pathway creates energy by breaking down glucose during glycolysis. During this process glucose is metabolized into pyruvate- a metabolic product of the energy producing process . If oxygen is limited, as it would be during intense exercise, the pyruvate is converted into lactate which allows glucose breakdown to continue. A byproduct of high lactate levels is an increase in acidity in the muscle cells. The acidity produces the pain we feel during high intensity exercise (Roth et al., 2006).

Perceived effort can have a significant effect on endurance performance in many different ways. In one study, Andreacci et al., (2002) used frequency of encouragement as a way to change PE. In theory, hearing encouragement from outsiders would reduce the perceived effort athletes experienced during a VO2 max test on a treadmill. VO2 max is a test to determine the maximum amount of oxygen an athlete can utilize during exercise. During the test athletes will run on a

treadmill while wearing a mask that measures oxygen consumption. Endurance running is largely aerobic and therefore VO2 max is a good indicator of performance. The participants all performed a test without any encouragement and then a week later were separated into four groups that completed the VO2 max test again. The two groups in the VO2 max test that received verbal encouragement every 20 and 60 seconds improved significantly more on the second trial relative to groups in the infrequent, every three minutes, and no verbal encouragement groups (Andreacci et al., 2002).

In the above study by Andreacci et al., (2002) encouragement must have decreased the athletes perceived effort during the VO2 max test. The encouragement could have reminded the athletes that others were watching them perform, and therefore increased their motivation through social facilitation (Andreacci et al., 2002).

Another study by Blanchfield et al., (2014) manipulated perceived effort through unconscious visual cues. Interested researchers theorized that the effort-based decision making within the psychobiological model would be altered based on visual cue manipulations on perception. This experiment had cyclists perform an endurance test while viewing happy or sad faces on a screen in front of them. Cyclists who were shown happy faces performed significantly better than the group who were subliminal primed with sad faces. The researchers theorized that the happy faces affected the participants' perceptions unconsciously and reduced perceived effort, which in turn allowed them to perform better (Blanchfield et al., 2014). This study displays just how easily PE can be manipulated and how that manipulation can have significant effects on performance.

In a similar study by Pageux et al., (2014) participants completed pre-test tasks designed to affect perceived effort. The experimental group completed an incongruent Stroop task that was

significantly associated with slower times in a 5 kilometer race when compared to a control group. The scientists concluded that the incongruent Stroop task caused participants to experience a higher level of PE, likely due to mental fatigue, and therefore choose a slower pace to run (Pageaux et al., 2014). In this experiment the athletes who completed the Stroop task ran significantly slower times due to some form of raised perceived effort. This experiment is an example of a closed loop test while the experiment above, conducted by Blanchfield et al., was an open loop test. Notably, the manipulation of perceived effort resulted in a significant change in performance during both tests.

Multiple studies have shown that perceived effort can affect endurance performance (Blanchfield et al., 2014, Bar-Eli et al., 1997, Pageux et al., 2014, Andreacci et al., 2002, Smirmaul et al., 2013). There has been less research examining how athletes can train their PE and use it to improve their performance. One study conducted by Bar-Eli in 1997 comes close to that idea. It examined athletes' goals during training. Groups were split by how much their goals increased compared to their already achieved times. Groups that had unreasonable goals (a percent increase of over 40%) as well as a group with general goals, non-specific achievement ideals, improved significantly less than groups with easy or difficult but attainable goals (Bar-Eli et al, 1997).

This study, Bar-Eli et al. (1997), suggests that athletes can influence their own performance based on what goals they choose for themselves. Using Marcora's application of the psychobiological model, we can assume that athletes who set goals that were more attainable experienced an increase in motivation as they came close to achieving those goals and were therefore able to ward off a rise in perceived effort more effectively versus athletes whose goals

were out of reach or non-specific. When athletes have high motivation they experience less perceived effort (Smirmaul et al., 2013).

The question remains- how can athletes train in hopes of decreasing their capacity to perceive effort at a given pace while racing? How can they experience a higher percentage of their maximum physical output without experiencing exhaustion? Samuel Marcora points to two explanations. When athletes train, they are not only training to increase their physical capabilities but they are also reducing their perceived effort at a given pace. Athletes have also been shown to ward off a rise in perceived effort if high motivation is present. In a cycling test participants underwent muscle biopsies after reaching 100% VO2 max and exhaustion. It was found that on average the cyclists had enough energy in their muscles to continue exercising at 100% VO2 max for seven to eight minutes after reported exhaustion (Sherman, 2021). This is yet another study that suggests that an athlete's performance is limited by psychology and not his or her physiology.

Marcora's findings suggest two routes in which athletes can improve performance by decreasing PE. Firstly, they can train, which will indirectly make their mind more adept at PE (Smirmaul et al., 2013). The specifics of this training remain unclear, but can be inferred based on what we know about distance running. Intervals play a large part in most running programs. When running intervals at a given pace the recovery time, in between reps, is a variable between different programs. When athletes take longer rests they will have recovered more from rep to rep and experience less perceived effort while running at a given pace versus if they took shorter reps.

The second route includes finding ways to increase motivation. Acceptance and commitment therapy has been shown to increase exercise tolerance and therefore performance

(Ivanova et al., 2015). This study suggests that focusing on ideas such as acceptance, commitment, and motivation during therapy will help to increase an athlete's performance through a reduction in perceived effort.

Focusing on motivation can take many different forms. In one study athletes were shown to perform better in races that included a rival compared to races that did not include a rival athlete (Kilduff et al., 2014). This study suggests that focusing on external factors that are associated with an athlete's individual motivations can lead to an increase in performance through a decrease in PE.

Currently the bulk of endurance running training is focused on fitness building while little emphasis is put on the psychological aspects of running. This can be problematic as overuse injuries such as stress fractures, plantar fasciitis, iliotibial band syndrome, are very common in highly trained distance runners (Monten, 2017).

Specifically in collegiate programs coaches push their athletes to overtrain in a method that is often described with the metaphor of *throwing twenty runners against a wall, 5 will get injured, 5 will burnout, 5 will quit, but at the end of the season you'll have 5 really fast runners.* Collegiate track and cross country only needs three to seven athletes to score, meaning the rest of the team has no impact on the team's success. College programs often fall into the trap of training athletes too hard in hopes that they will improve at a rapid pace, due to the fact that there is a high turnover and injury rate in college programs, because of how the teams are trained. There is little to no concern as to the long term development or injury prevention of the athletes (Daniels, 2014).

The use of training for perceived effort could be useful in reducing injury and burnout as it would include less intense and physically demanding training than the commonplace fitness

training that is predominantly used today. Marcora in 2021 describes training for fitness as using the physiological model. The physiological model focuses on developing the physiology of a runner or in other words improving the VO2 max, lactic threshold, and biomechanics of a runner. He states that while improving fitness is important, real performance gains are made through improvements in perceived effort which occur simultaneously when athletes focus on improving fitness. If athletes were instead focused on the psychobiological model, in turn focused on reducing PE at a given pace with the byproduct being improved fitness, athletes could experience greater performance than the commonplace focusing on the inverse (Sherman, 2021). In other words, all performance increases are due to a reduction of PE at a given pace, because if a pace doesn't feel as intolerable the athlete will increase their pace. This can be a byproduct of physiology fitness training but because endurance performance is limited by psychology and not physiology it makes sense to reverse the commonplace practices of endurance training and focus on reducing PE at a given pace, while allowing physiological fitness increases to be the byproduct.

There are multiple ways in which athletes can focus on running at faster paces while experiencing less PE. Focusing on motivation increases the amount of time an athlete can run before experiencing exhaustion (Smirmaul et al., 2013). Certain shoes have been shown to allow runners to run at a given pace while experiencing less PE (Joubert et al., 2021), this would in turn allow athletes to practice reducing PE at the given pace. When running intervals athletes who take longer rests will experience less fatigue during the interval, this should improve the perceived effort while running at that pace, as opposed to taking shorter rests which would train specific physiological energy systems (Daniels, 2014). Using these techniques athletes can focus on the psychobiological model when running and therefore it can be theorized that trained

runners will improve to a greater degree on the second of two five kilometer races when training for a reduction of perceived effort at a given pace versus runners who focus on fitness building workouts.

My proposed study will use the techniques that have been shown to support their reducing PE effects and compare them to commonplace fitness building techniques. The proposed experiment will compare distance runners' performance after focusing on the psychobiological model versus athletes focused on the physiological model over a four month training period. The participants will complete a five-kilometer race before and after the training period. Both the frequency of injuries and performance will be measured.

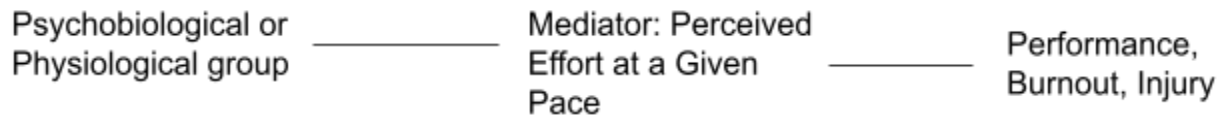
Methods

Aim	Variable	Measure/Indicator
Does this intervention increase performance/ decrease injury/burnout risk.	Training Philosophy (Psychobiological focus: reducing PE at a given pace vs Physiological: improving physiological indicators)	Percent change in performance between two 5k races. Self reported injury/burnout

Question	Method	Hypothesis
Does focusing on reducing PE at a given pace lead to an increase in performance/ decrease in injury/burnout risk when compared to more typical distance running training programs?	N= 6 collegiate XC teams. Manipulation: PE group practices running at pace with less effort, physiological group trains to improve physiological indicators	The Psychobiological group will display a significantly greater performance increase between the two races because of a greater focus on psychology. PE group will also have less injury and burnout because of inherently less demanding training.

Study Design

This study will split the participants into experimental (psychobiological) and control (physiological) groups. Those groups will complete a 5k race before and after manipulation. The dependent variable is performance change between the two races. The independent variable is training over a four month period. This training will either be a focus on reducing perceived effort at a given pace (psychobiological), or focusing on increasing physiological indicators. This study will determine if a greater percent change comes from focusing on a physiological model or a psychobiological model by manipulating PE at a given pace, while reducing overall intensity in the experimental group. Athletes will also fill out a questionnaire at the end of each week where they will report on training and indicate any signs of burnout or injury.



Participants

Participants will include six collegiate cross country teams. Athletic administration and coaches will be informed about the effective and performance focused training their athletes will receive and thus be influenced to allow training alterations to their athletes. Athletes will also be given a pair of running shoes according to their group, which will incentivise their participation. Division will be ignored in favor of performance when recruiting participant teams. Teams previous year average time must be faster than 30:00 for 8k and 27:00 for 6k. These numbers were calculated by finding the median average team time for the men's and women's Division 3 National Cross Country Championships and then finding a time that is 87% as fast and then rounding to the closest 15 seconds. Most collegiate programs will be well under these time

cut-offs but including them is necessary to remove teams that do not have a highly trained distance running squad.

High performing distance runners are necessary to negate pacing inconsistencies over the 5-kilometer races and will make the results of the experiment more applicable to the distance running community. Athletes will be screened for pre-existing injuries and excluded from the experiment. The six teams will have athletes within each team randomly divided into control or experimental groups. A collegiate cross country team is made up of about 30 athletes, therefore the population size is estimated to be around 180.

The collegiate teams will be from the United States ideally from diverse environments. It should be noted that at minimum 3 out of the 6 teams should be located at sea level, or within 1,000ft of sea level. All other demographic traits will be ignored, as to ensure the applicability of the experiment's results to all the widest possible population of endurance athletes. Although conditions such as gender, sex, etc. should be noted and measured after the study has taken place in order to determine if any of these factors resulted in significant statistical differences.

Measures

A 5-kilometer race was chosen as a measure for a multitude of reasons. Firstly, it is a largely aerobic event and thus applicable to endurance athletics. It is also the most common distance run in United States racing. Athletes will have already become very familiar with the event as it is the distance used in highschool cross country. It is also very common for cross country teams to use a within team 5k race to prepare for the season, as such this experiment will be little disturbance to the cross-country season.

The first of two 5-kilometer races will take place in August and the second in November. This is the approximate timeline for a collegiate cross-country season. The course run for the

races should be run on a track or road. The course should not include more than 100 ft of elevation gain or loss as to keep trial consistency between all measures. Because we are using percent change as a measure between two races it is acceptable that courses will not be exactly the same between different teams. Coaches should schedule the races to have as similar environmental conditions as possible. For example factors such as mud, rain, or extreme humidity could add a confounding variable as some athletes may thrive in certain conditions and perform differently based on environment rather than training manipulations. Coaches will report on the conditions of the races. The report should include temperature, humidity, and weather.

All other factors should be kept consistent between the two races. These include time of day, spectators, order of event, timing methods, footwear, external pacing methods, gps watches, competition heats, instruction, effort, and awards. It is important to note that the 5k race should be treated as a race and thus athletes should give 100% effort in both. This should not be an issue as cross country athletes are asked to do this 8-12 times a season.

At the end of every week during the study athletes will be required to complete a short questionnaire. The questionnaire will ask athletes to report on training to ensure that athletes are following the prescribed plan. Participants will be asked if they followed all prescribed workouts. If not they will be tasked with explaining how their training deviated from what was prescribed.

It will also ask about injuries and athletic burnout. The questionnaire will ask to report any significant injuries, running related or not. Athletes will be tasked to describe the injury in as much detail as possible. Injuries will be classified as training related or not. Any injuries that are overuse associated or originally occurring while running are training related. Injuries that occur due to a singular non-training related moment will be deemed non-training related. For example

if an athlete breaks a toe because they dropped something heavy on it, that injury would be deemed non-training related and not factored into the analysis of the experiment.

To report burnout athletes will complete the Athlete Burnout Questionnaire. The ABQ measures three dimensions of athletic burnout, these include emotional and physical exhaustion, reduced sense of accomplishment. This questionnaire has been shown to accurately and reliably indicate endurance athletes who are or are not experiencing athletic burnout. (ABQ; Raedeke & Smith, 2001).

Fig 1.1 Athlete Burnout Questionnaire. Response is a 5-point Likert scale: 1-almost never, 2-rarely, 3-sometimes, 4-frequently, 5-almost always. Items 1 and 14 are reverse scored. RA-reduced accomplishment, E=emotionally or physically exhausted, D= devaluation.

Item	Subscale	Question
1	RA	I'm accomplishing many worthwhile things in running
2	E	I feel so tired from my training that I have trouble finding energy to do other things
3	D	The effort I spend in running would be better spent doing other things
4	E	I feel overly tired from my running participation
5	RA	I am not achieving much in running
6	D	I don't care as much about my running performance as I used to
7	RA	I am not performing up to my ability in running
8	E	I feel "wiped out" from running
9	D	I'm not into running like I used to be

10	E	I feel physically worn out from running
11	D	I feel less concerned about being successful in running than I used to
12	E	I am exhausted by the mental and physical demands of running
13	RA	It seems that no matter what I do, I don't perform as well as I used to
14	RA	I feel successful at running
15	D	I have negative feelings toward running

Training Plans

The control/physiological model training group will use the Jack Daniels' 5k training plan as described in *Daniels' Running Formula Third Edition* (Daniels, 2014). Jack Daniels has a PHD in exercise physiology, has published multiple training books, and has coached multiple collegiate and olympic distance running teams. His training formula is heavily based on physiological markers, specifically a VDOT score which is an altered version of an athlete's VO2 max. Daniels' training philosophy is based around the idea that an athlete's performance is influenced by six trainable factors. These factors include, the cardiovascular system, the muscle's ability to use oxygen, lactate threshold, VO2 max, leg turnover, and running economy. The Daniels' running formula includes four phases of training. Each phase changes in prescribed paces and intensities of intervals (Daniels, 2014). Notably, psychological factors are not included as focuses in his training philosophy.

The experimental group/psychobiological group will take Daniels' running formula and make alterations to it that will result in a greater focus on psychological factors. In both training plans athletes are required to run intervals at certain paces based on their VDOT scores. In the experimental group all rest time between intervals will be multiplied by 1.5 and all continuous tempo runs will be changed to mile repeat sessions with 1 minute rest per mile. The increase in rest time will train the physiological system less effectively as the athlete will spend less time at the desired intensity. The increase in rest time will also decrease the perceived effort at a given pace. After the first races athletes or coaches will enter their times in a VDOT calculator. The calculator will give them their paces at different intensities. These paces are labeled at R, H, I, T, and E in the training plans below. R stands for repetitions and is the fastest pace. R pace feels almost like an all out sprint. H stands for hard and is a pace that athletes can hold for about 90 seconds. I stands for interval and is the main pace used for race pace intervals. T stands for threshold and is used for tempo runs. Lastly, E stands for easy and is run on non-workout days.

Athletes mileage and rest days between workouts are to be determined by their coaches. The coaches will be instructed to keep methods uniform over their entire team and report on general training philosophies that may be notable to the experiment.

Fig. 1.3 displays the control group's training plan. Fig. 1.2 displays the experimental group's training plan. Numbers are in either meters, or miles only when T pace is subscribed. Rest times are in minutes or distances followed by the abbreviation jg.

Fig. 1.3 Physiological/Control Training Group. Unaltered Jack Daniels Training Plan

Week	Workout 1	Workout 2	Workout 3
1	Long Run (20-25% of weekly mileage)	4x200R w/200jg+ 6x400R w/ 400jg+ 4x200R w/ 200jg	4x200R w/200jg+ 4x1T w/ 1 min rest+ 4x200R w/200jg

2	Long Run	6 sets of (200R x2 + 400R) 200jg+400jg	5x 1T w/ 1 min rest+4x200R w/ 200jg
3	Long Run	4x200R w/200jg+ 8x400R w/ 400jg+ 4x200R w/ 200jg	10x 2 min H w/ 1 min jog
4	Long Run	4x200R w/200jg+ 8x400R w/ 400jg+ 4x200R w/ 200jg	4x200R w/ 200jg+ 3T+ 2x1T w/ 1 min+4x200 w/ 200jg
5	Long Run	6 sets of (200R x2 + 400R) 200jg+400jg	6x 1T w/ 1 min rest+4x200R w/ 200jg
6	Long Run	12x400R w/ 400jg	2x 4H w/ 3min +3x3 min H w/ 2 min, + 2x2 min H w/ 1 min
7	Long Run	6x 1200I w/ 3 min	6x 1k I w/ 400jg
8	Long Run	3T+ 4x200R w/ 200jg+ 2T	6x 1k I w/ 400jg
9	Long Run	8x3 H 2min jg	5x1200I w/ 3 min jg
10	Long Run	3x2T w/ 2min +4x200R 2/ 200jg	5x1200I w/ 3 min jg
11	Long Run	7x3H w/ 2min jg	3T+4x200R w/ 200g+3T
12	Long Run	8x3H w/ 2 min jg	4x1 T w/ 1 min +2T
13	Long Run	6x4H w/ 3 min jg	3x2T w/ 2 min rest
14	Long Run	3T+1E+2T	6x4H w/ 3 min rest
15	Long Run (90 minute cap)	6x4H w/ 3 min jg	3x2T w/ 2 min rest
16	Long Run (90 minute cap)	3x1T 2min	**races 2**

Fig. 1.2 Psychobiological/experimental Training Group. Altered Jack Daniels Training Plan

Week	Workout 1	Workout 2	Workout 3
1	Long Run (20-25% of weekly mileage)	4x200R w/300jg+ 6x400R w/ 600jg+ 4x200R w/ 300jg	4x200R w/300jg+ 4x1T w/ 1.5 min rest+ 4x200R w/300jg
2	Long Run	6 sets of (200R x2 + 400R) 300jg+400jg	5x 1T w/ 1.5 min rest+4x200R w/300jg
3	Long Run	4x200R w/300jg+ 8x400R w/ 600jg+ 4x200R w/ 300jg	10x 2 min H w/ 1.5 min jog
4	Long Run	4x200R w/300jg+ 8x400R w/ 600jg+ 4x200R w/ 300jg	4x200R w/ 300jg+ 3T+ 2x1T w/ 1.5 min+4x200 w/ 300jg
5	Long Run	6 sets of (200R x2 + 400R) 300jg+600jg	6x 1T w/ 1.5 min rest+4x200R w/ 300jg
6	Long Run	12x400R w/ 600jg	2x 4H w/ 4.5min +3x3 min H w/ 3 min, + 2x2 min H w/ 1.5 min
7	Long Run	6x 1200I w/ 4.5 min	6x 1k I w/ 600jg
8	Long Run	3T+ 4x200R w/ 300jg+ 2T	6x 1k I w/ 600jg
9	Long Run	8x3 H 3min jg	5x1200I w/ 4.5 min jg
10	Long Run	3x2T w/3min +4x200R 2/ 300jg	5x1200I w/ 4.5 min jg
11	Long Run	7x3H w/ 3min jg	3x 1T w/ 1 min +4x200R w/ 300g+3 x1T w/ 1 min
12	Long Run	8x3H w/ 3 min jg	4x1 T w/ 1.5 min +2x 1T w/ 1 min
13	Long Run	6x4H w/ 4.5 min jg	3x2T w/ 3 min rest
14	Long Run	3x1T w/ 1 min	6x4H w/ 4.5 min rest

		+1E+2x1T w/ 1 min	
15	Long Run (90 minute cap)	6x4H w/ 4.5 min jg	3x2T w/ 3 min rest
16	Long Run (90 minute cap)	3x1T 3min	**races 2**

Athletes in the experimental group will be required to wear either the Asics Metaspeed Sky, Nike Vaporfly, or Nike Alpha Fly during all interval and tempo runs. These three shoes have been shown to significantly increase running performance and as such will make the perception of effort while running at a certain pace easier when compared to other shoes (Joubert, 2022). Athletes in the control group will be required to wear shoes that are non carbon plated in intervals. Any intervals that are at or faster than mile pace will be excluded from any shoe requirement as the listed shoes were not made for paces at that speed. Athletes will be given either the *super shoes* or a control group shoe at the outset of the experiment, as well as a fresh pair after 3 months of training.

Procedure

After recruitment and division into randomized groups, teams will complete the first of two five-kilometer races. Athletes will be instructed to give 100% effort in both races and winners will be rewarded with medals.

After the races athletes in the control group will complete Jack Daniels' 5-kilometer training plan to exaction while the experimental group will complete an altered version. Athletes in the experimental group will wear super shoes as defined by Joubert, 2022. Athletes in the control group will wear non-carbon plated alternatives. The two differences between the groups are an increase in rest time between intervals as well as the performance enhancing shoes. Both

of these manipulations will make the running during the intervals less effort at the prescribed pace when compared to the control group. This means that athletes in the experimental group will spend their time running at their prescribed paces with less perceived effort compared to the control group. The control group will experience more perceived effort as their intervals will be more effortful at a given pace, as such their workouts will be more difficult and more physiologically impactful.

All athletes will complete a questionnaire at the end of each week that will measure athletic burnout, training success, and injuries. Athletes who deviate from their prescribed training plan in a significant manner will be excluded from the experiment. Athletes training related injuries and athlete burnout will be noted.

After the four month training period athletes will again complete a five-kilometer race on the same course that they completed the first race. Athletes will be instructed to give 100% effort and winners will be rewarded with medals. All conditions should be kept as similar as possible to the first race as described in the study design section of this document. A statistical analysis will then measure the percent change between the two groups as well as the rate of occurrence of injuries and athletic burnout. It will also measure for other factors when present. These factors include, sex, gender, elevation, environment, coaching style, and speed; although these factors are not hypothesized to have any significant effects on the results of the experiment.

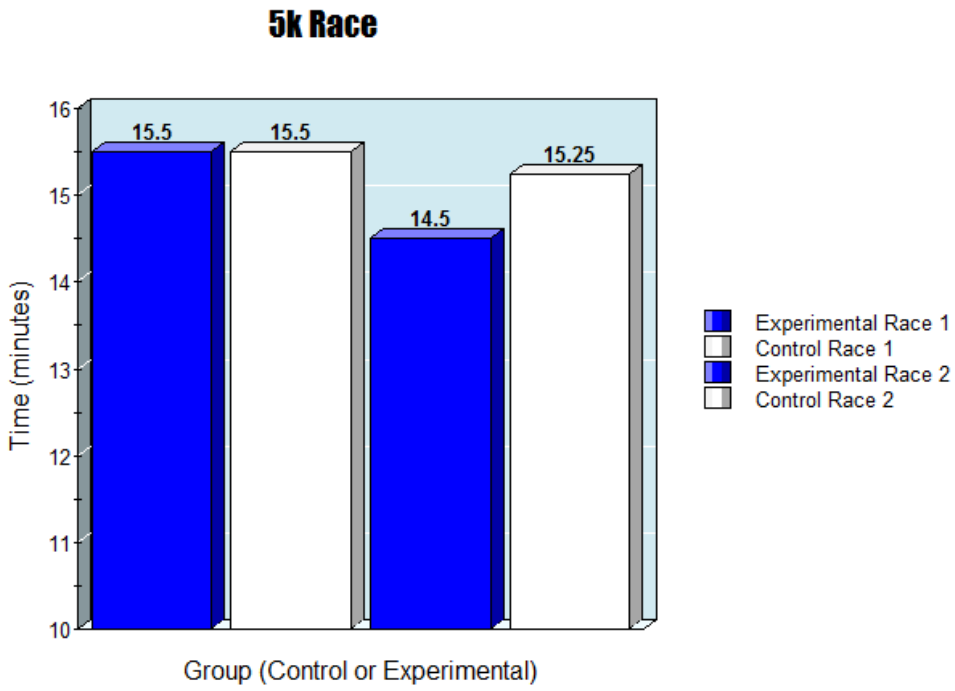
Results

The expected results are as follows. Using independent samples t-test athletes in the psychobiological group (experimental) will display a significantly greater increase in speed between the first and second 5k races when compared to the physiological (control) group. Both

groups will show a performance increase but the experimental group's increase will be a significantly greater percentage than the control group. These effects are predicted to be due to the mediating factor that is a reduction in perceived effort at a given pace. These effects are predicted to be due to the mediating factor that is a reduced effort at a given pace during training.

Fig 1.4 represents predicted results. Both groups would run an average of 15:30 in the first race. In the second race the experimental group would improve to an average time of 14:30 while the control group would improve to an average time of 15:15.

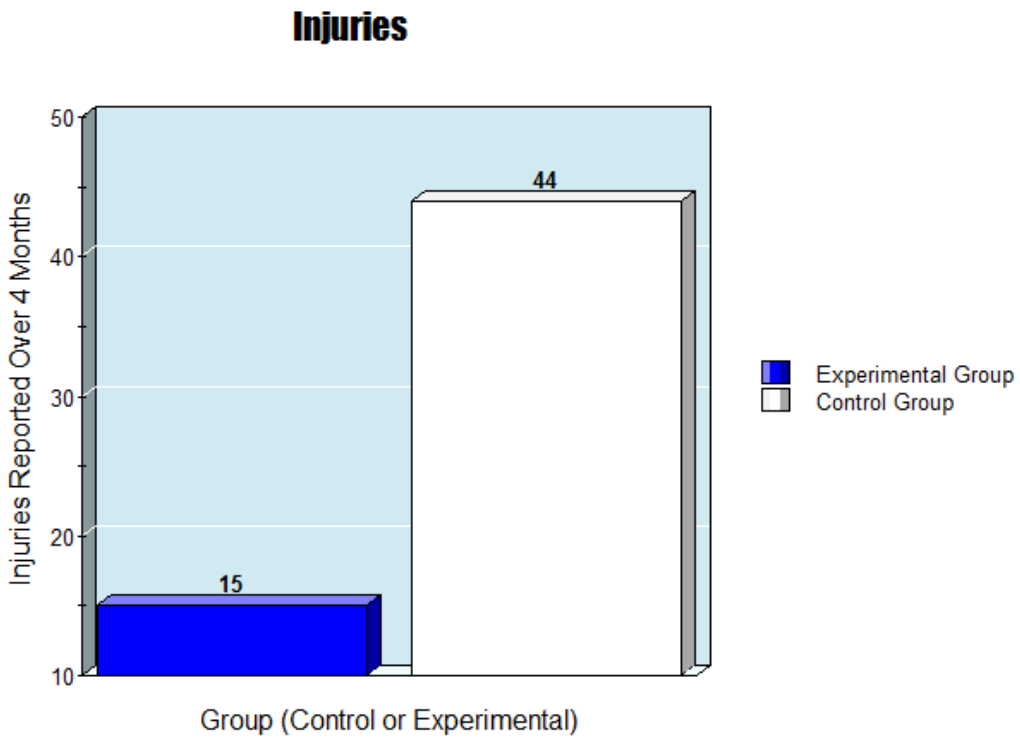
Fig 1.4 5K Race Results



According to independent samples T-test athletes in the experimental group will also report significantly less training related injuries when compared to the control group. This effect will be due to the reduction of effort in the experimental group's workouts. Figure 1.5 represents

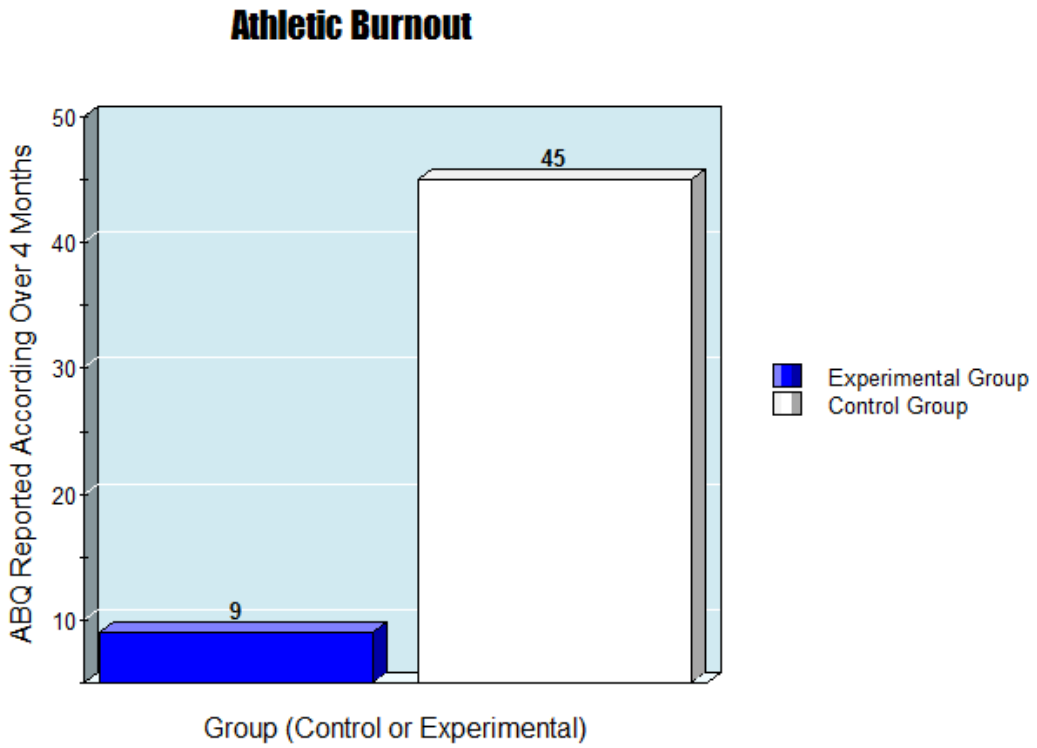
predicted result that includes 15 training related injuries reported by the experimental group and 44 training related injuries reported by the control group.

Fig 1.5 Injuries



According to independent samples T-test athletes in the experimental group will also report significantly less athletic burnout when compared to the control group. This effect will also be due to the reduction of effort in the experimental group's workouts. Figure 1.6 represents a predicted result that includes 9 reports of athletic burnout by the experimental group and 45 reports of athletic burnout by the control group.

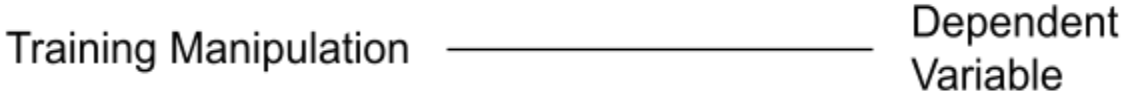
Fig. 1.6 Athletic Burnout

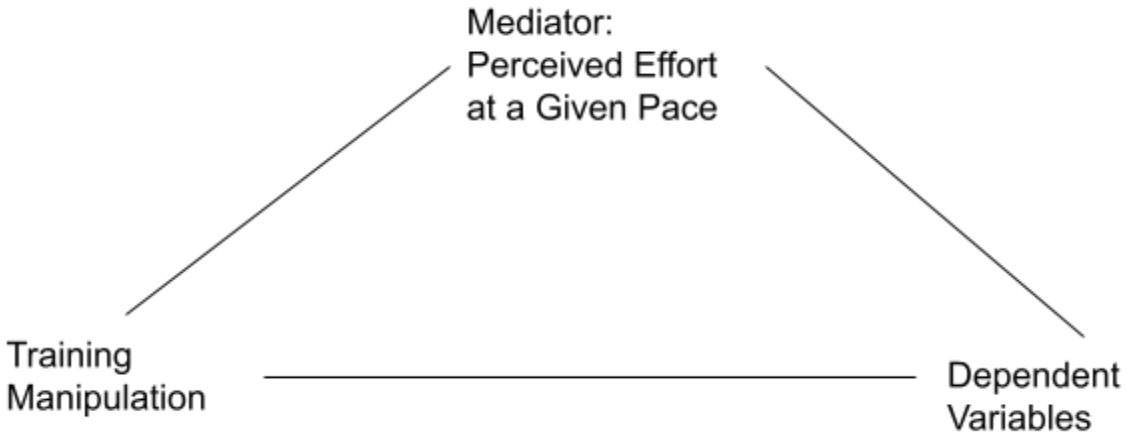


Mediational Analysis

I predict that the effect of training on the dependent variables will be mediated by perceived effort at a given pace. Following Baron & Kelly (1986), three regression analysis steps will be conducted to test the mediation hypothesis for each dependent variable. The mediation hypothesis in this experiment is that the training manipulation (independent variable) influences the dependent variables (injury, athletic burnout, performance) through a mediator. That mediator is a reduction of perceived effort at a given pace. Figure 1.7 displays the relationship between the variables.

Fig. 1.7 Mediation Analysis





Through the three regression analysis steps we can determine to what degree the mediator is affecting the dependent variable. The three steps will need to be done three total times to determine the effects on the three dependent variables: performance change, injuries and athletic burnout.. The first regression will determine if the independent variable (training manipulation) predicts the dependent variables. The expected results would indicate that the independent variable significantly influences the dependent variables.

The second regression analysis will determine if the independent variable significantly influences the mediator. The expected results would indicate that the independent variable does significantly influence the mediator.

The third regression analysis will determine if the independent variable and the mediator influence the dependent variable. The expected results would indicate that the independent variable does not significantly influence the dependent variable once the mediator is controlled.

If all three of these conditions are met the mediator (perceived effort at a given pace) would have influenced the dependent variables instead of some other factor. For example, the training manipulation of a reduction of perceived effort at a given pace would be responsible for the effect on the dependent variable.

Discussion

If the expected results come to fruition, meaning the experimental group displays a significant increase in performance and decrease in reported injury and athletic burnout, it would alter our fundamental understanding of endurance training and what makes an athlete fast. While many coaches give lip service to the psychological aspects of distance running, there is little emphasis put on it when building a training plan.

While many training camps are likely training in the same manner as the experimental group in this proposed experiment, they would now have scientific evidence that supports their training habits. With a focus on the psychobiological system when training, athletes could break new barriers, records, and push the sport to new levels.

It is important to note that expected results from this experiment would not indicate that physiological indicators are not important when determining how an athlete will perform. Instead, it would suggest a reordering of perspective as to how an athlete improves. While athletes who improve their physiological attributes will likely improve their performance, it is their brain's perception of effort that will allow an athlete to run at a faster pace than previous attempts. When an athlete increases a physiological indicator their old race effort will be perceived as less effortful and therefore they will speed up. The final step in speeding up is perception of effort and thus that should have more of a focus on manipulating in training than what is commonplace in the distance running world now.

The expected results of this experiment will indicate that a focus on the process of the brain perceiving effort at a given pace can be reduced and thus the athlete will run faster and that will be more effective than focusing on improving physiological indicators. Essentially, psychology is the limiter to performance not physiology and as such athletes should focus more so on psychology.

In 2017 Nike put huge amounts of research and development into what they called the *Breaking Two Project*. They spent millions of dollars researching the most advanced training methods, developed new shoe technology, hired the best runners in the world and set up a course that was designed to help an athlete finally break the two hour barrier in the marathon. A feat that has never been done and has become culturally akin to Roger Bannister breaking four minutes in the mile. The project spawned the "super shoe" industry as everything about the race was planned, researched, and detailed to the most minute detail. Even the shorts and socks the runners wore were the result of over three years of research and development (Breaking2, 2017).

Nike sponsored three athletes, Eliud Kipchoge, Zersenay Tadese, Lelisa Desisa, as well as thirty pacers to run the race. In 2017 only Eliud Kipchoge finished the event while Tadese and Desisa dropped out around the halfway point. Kipchoge finished about twenty seconds over the two hour mark but National Geographic made a documentary about the event anyway (Breaking2, 2017). It was not until 2019 with a second attempt that Kipchoge finally broke the two hour marathon; although because it was not an official race it does not count as a world record.

The official marathon record is two hours, one minute and nine seconds, set by Eliud Kipchoge at the Berlin Marathon. It is possible that with this new information on training top athletes can implement the psychobiological model of training and use it to help run under two hours in an official marathon event.

The experimental group's training plans are inherently less effortful both physically and mentally on the athletes. The manipulations were designed to make running at the same pace less effortful through shoe choice and rest time between intervals. Due to the increase in rest and reduction of effort in workouts the athletes in the experimental group are likely to experience less

injuries and athletic burnout. Both of these results are both common and harmful in the distance running community. If the expected results are realized it would help to reduce overuse injuries and athletic burnout that plague the industry.

Some of the top distance runners in the world may already be moving towards a psychobiological training approach without realizing it. Eliud Kipchoge, the marathon world record holder, olympic gold medalist, and man who is widely regarded as the best marathon runner of all time, has been quoted numerous times saying that he never pushes himself past eighty percent effort in training (Cacciola, 2018).

Similarly, the Norwegian method of double threshold training has become revolutionary in the elite distance running world. Popularized by the Ingebrigsten camp, the Norwegian double threshold training consists of running two, relatively easy, workouts in a day. The workouts are less intense than traditionally designed training and thus they are able to perform two in a day. In these workouts the Ingerbrigsten brothers run intervals between 400 meters to 3000 meters with the greatest volume from 400 meters to 1000 meters. Their recovery time taken between intervals ranges from just 20 seconds to 1.5 minutes. All intensities are limited by lactate threshold and measured by finger pricks during the workouts. They complete workouts like these two times in a day, twice a week at paces that are much slower than other elite athletes run more traditional workouts. Then they complete one more workout of a different type to make for five total workouts in a week. The fifth workout has been reported to be a hill sprint workout in the form of 20x200 meters uphill with a jog back recovery (Casado et al,. 2023).

While the Norwegian method of double threshold training is intensely focused on physiological indicators(blood lactate levels) they are an instance of elite athletes training in a less intense manner and improving performance to a great degree. The fifth weekly workout hill

session can also be viewed as perceived effort training. The hill makes running at a pace harder and then when they get back to the track their perception is easier when compared to the hill.

In comparison the Igebrigtsen camp in Norway and the Kenyan camp where Kipchoge trains are both less intense from an internal effort perspective than many United States collegiate programs. My own personal experience running at SUNY Oswego consisted of workouts significantly more demanding than what the Igerbrigsten's do and surely more effortful than the 80% Kipchoge completes. It should be noted that effort and intensity are relative to the individual athlete's skill levels. Kipchoge and the Igebrigsten brothers are running much faster than US collegiate athletes but their intensity levels are lower. The top distance running athletes in the world are proving that when it comes to training, more effort is not always the best route to improving.

Many US distance runners who attempt the Norwegian double threshold method find it difficult because they have to hold back so much during the intervals as they are used to working much harder during track sessions. If the expected results of this experiment are realized, hopefully, they can help to decrease the overtraining phenomena that exists in US distance running culture.

There is currently an extremely high burnout, dropout and injury rate in US collegiate distance running (Daniels, 2014). This is likely associated with exceptionally intense and effortful training methods. Coaches feel they must train athletes very hard in order to stimulate fast adaptations and quick increases in performance. This is a risky training method, as a large percentage of athletes experience athlete burnout and injury. As a result the dropout rate for college distance programs is high. It is a vicious cycle that feeds itself. Coaches feel they must force athletes to improve quickly because of the high turnover of athletes, yet the high turnover

rate is likely due to the overly intense training. If the expected results are realized it could help change this problem. Coaches will see that athletes can improve greatly and at the same time decrease the athlete burnout and injury rate.

The results of this experiment are reliant on collegiate athletes following their training programs as well as accurately reporting when they do and don't. If an athlete felt embarrassed or scared to admit their skipping or altering of their training and reported inaccurate training it would falsify the results.

Coaching style could also be a limiter. If a coach incorrectly instructs athletes it could be a confounding factor. Coaches can also have different instructions on non workout days such as, weight training, easy running intensity. If athletes in the experimental group choose to replace their workout intensity with more effortful lifting and easy running it would reduce the effectiveness of the experiment.

Race frequency could also play a role as a limiting factor. It is unlikely that the six different teams will have the same race schedules and could therefore come into the second five-kilometer race in different conditions. There is also likely to be weather differences between the two five-kilometer races. The first completed in August will likely be hot and humid while the second in October could be cold. There could also be the factors of rain, snow, and wind to take into account.

The use of percent change between races should mitigate most of these limiters. The six teams are randomly split into groups within their own teams. Therefore, a team who completed their first race in hot humid conditions and their second in cool conditions are subject to the same conditions across both the experimental group and control group. The only way the change in environmental conditions would be a limiting factor is if the specific environmental conditions

have an interaction with one group's manipulation and not the others, which seems unlikely. Coaches are informed to treat both groups uniformly, the only difference in training being the prescribed workouts. This should mitigate coaching style limitations.

Follow up research could take the ideas in this experiment to a more extreme level with the use of a gravity altering treadmill. AlterG is a company who makes treadmills with a device that alters the weight that an athlete has to move while running. When weight is reduced, running becomes much less effortful. An experiment could be done where athletes are divided into three groups. The first group would be the altered gravity group and would perform all their workouts on the AlterG treadmill. The second group would perform all their workouts on a track and the third group would split their workouts between the two. The experiment could use the same parameters as this experiment and have two five-kilometer races spaced between four months of training.

Predicted results of this suggested study would likely be that the group that mixed the track and altered gravity treadmill would improve the most. The two groups who exclusively used the treadmill and exclusively used the track would not be significantly different from each other. This is because the altered gravity treadmill would make the workouts possible to complete with so little effort that physiological indicators would not improve much. It would make up for this deficiency with a rapid increase in biomechanical efficiency and reduction of perceived effort at a given pace but as stated above the physiological metrics are still important in improving performance. Although, the group that exclusively used the altered gravity treadmill would have a huge reduction of athlete burnout and injury, as the reduction of gravity would reduce impact and thus reduce overuse injuries.

This suggested experiment would help to provide evidence to support the idea that training harder isn't always better and athletes should instead focus on finding ways to make running feel easier. It would also prove the effectiveness of the AlterG treadmill as a training tool. Although, these treadmills are very expensive and not likely to be used by non-professional athletes.

Further research could attempt to measure the effectiveness of other mental processes that could have a significant impact on running performance. Two such processes include the presence of a rival and commitment/acceptance therapy. Experiments could be run where athletes experience or don't experience acceptance/commitment therapy. Other experiments could find ways to manufacture rivalries and then measure results.

References

Andreacci, J.L., L. M. LeMura, S. L. Cohen, E.A. Urbansky, S.A. Chelland, and S. P. von Duvillard. "The Effects of Frequency of Encouragement on Performance During Maximal Exercise Testing." *Journal of Sports Science* 20, no. 4 (2002): 344-352.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51, 1173-1182.

Bar-Eli, M., G. Tenenbaum, J. S. Pie, Y. Btesh, and A. Almog. "Effect of Goal Difficulty, Goal Specificity and Duration of Practice Time Intervals on Muscular Endurance Performance." *Journal of Sports Science* 15, no. 2 (April 1997): 125-135.

Blanchfield, A., J. Hardy, and S. Marcora. "Non-Conscious Visual Cues Related to Affect and Action Alter Perception of Effort and Endurance Performance." *Frontiers in Human Neuroscience* 11, no. 8 (2014): 967.

Breaking2, (2017). [Film] National Geographic.

Casado, A., Foster, C., Bakken, M., and Tjelta, LI., Does Lactate-Guided Threshold Interval Trainign within a High-Volume Low-Intensity Approach Represent the "Next Step" in the Evolution of Distance Running Training? *International Journal of Environmental Research And Public Health.* 20, no. 5 (2023): 3782.

Cacciola, S. (2018, September 14). *Eliud Kipchoge Is the Greatest Marathoner, Ever.* NY Times, https://www.nytimes.com/2018/09/14/sports/eliud-kipchoge-marathon.html

Daniels, J. (2014). *Daniels' Running Formula.* A.T. Still University in Mesa, Arizona.

Fitzgerald, M. (2015). *How Bad Do You Want It?: Mastering The Psychology of Mind Over Muscle.* Velopress.

Fitzgerald, M. (2014). *Run Stronger and Race Faster By Training Slower 80/20 Running.* New American Library.

Honea, D. M. "The Impact of Replacing Run Training With Cross-Training On Performance of Trained Runners." *Appalachian State University*, (December 2012).

Ivanova, E., D. Jensen, J. Cassoff, F. Gu, and B. Knauper. "Acceptance and Commitment Therapy Improves Exercise Tolerance in Sedentary Women." *Medicine and Science in Sports and Exercise* 47, no. 6 (June 2015): 1251-1258.

Joubert, Dustin P. and Jones, Garrett P., "A Comparison of Running Economy Across Seven Carbon-Plated Racing Shoes" (2021). *Faculty Publications*. 33. https://scholarworks.sfasu.edu/kinesiology/33

Kilduff, G. J. Driven to Win: Rivalry, Motivation, and Performance. *Social Psychological and Personality Science*, *5*(8), (2014) 944–952. https://doi.org/10kild.1177/1948550614539770

Monten, J. (2017). "Common Running Overuse Injury and Prevention." *Montenegrin Journal of Sports Science and Medicine, https://www.mjssm.me/?sekcija=article&artid=144#:~:text=Runners%20are%20particularly%20prone%20to,fractures%2C%20and%20patellofemoral%20pain%20syndrome*

Pageaux, B., R. Lepers, K. C. Dietz, and S. M. Marcora. "Response Inhibition Impairs Subsequent Self-Paced Endurance Performance." *European Journal of Applied Physiology* 114, no. 5 (May 2014): 1095-1105.

Raedeke, T. D., & Smith, A. L. (2001). *Athlete Burnout Questionnaire (ABQ)* [Database record]. APA PsycTests.

Roth, S. (2006). "Why Does Lactic Acid Build Up in Muscles? And Why Does it Cause Soreness?*" Scientific America, https://www.scientificamerican.com/article/why-does-lactic-acid-buil/*

Sherman, I. (2021) (The Podium Runner Endurance Podcast). *Ep 11-Prof. Samuele Marcora and the Psychobiological Model of Endurance Performance. https://podcasts.apple.com/no/podcast/ep-11-prof-samuele-marcora-and-the-psychobiological/id 1511998008?i=1000511464134*

Smirmaul, B. P., J. L. Dantas, F.Y. Nakamura, and G. Pereira. "The Psychobiological Model: A New Explanation to Intensity Regulation and (In)Tolerance in *Endurance Exercise." Revista Brasileira de Educacao Fisica e Esporte* 27, no. 2 (2013): 333-340.

Wall, B. A., G. Watson, J.J. Peiffer, C.R. Abbiss, R. Siegal, and P.B. Laursen. "Current Hydration Guidelines Are Erroneous: Dehydration Does Not Impair Exercise Performance in the Heat." *British Journal of SPorts Medicine* 49, no. 16 (August 2015): 1077-1083.

Appendices

Appendix A: Informed Consent

Informed Consent Agreement

Study Title: Mind Over Body: A Comparison of Psychobiological Versus Physiological Focused Distance Runners.,

Background: The goal of this study is to determine if a focus on the psychobiological or the physiological system of training is more effective for distance runners.

What you will do in this study: During your upcoming cross country season you will participate in two races with your team. The first will take place in August and the second four months later. During the four months between the races athletes will follow a prescribed training plan that either follows a traditional physiologically focus method or an altered plan with a focus put on the psychobiological model. Participants will be asked to fill out a weekly questionnaire that focuses on training patterns, injury, and athletic burnout. Races will be conducted where your coach chooses.

Risk, Benefits and Compensation: As with any rigorous training there are risks of injury, burnout, and stress. Benefits include a further understanding of endurance training and the opportunity to help further our understanding of the psychological mechanisms behind distance running. All athletes will be given a new pair of shoes as compensation for their participation, although the type of shoes will be determined by the participants group.

Your Rights and Confidentiality as a Participant: This is a voluntary study anytime a participant wishes to withdraw they may do so with no penalty. Your name will not be published, only the data associated with your participation.

Consent: Singing this form indicates that a participant is agreeing to participate in this study, affirming that a participant is at least 18 years of age, and has read this consent form.

Appendix B: Coach Instructions

Coach and/or Administrator Debriefing

Thank you for participating in this experiment. The researchers who have contacted you wish to further the industry's understanding of endurance training. Your participation helps with achieving this goal while also ensuring that you will be the first among many to become privy to this new information. Your athletes will participate in two 5k races once in the beginning of your season in August and again at the end of your season in November. Your athletes will be randomly assigned into two groups, the experimental and control. The control group will follow a traditional fitness building training plan, likely very similar to what you would prescribe yourself. The experimental group will complete an altered training plan that focuses on the psychobiological processes involved in running. It is important to note that we fully expect both groups to display improvement between the first and second time trials, our study is only measuring which group improves to a greater degree.

As the coach it is your job to administer the training plans and ensure the opportunity for athletes to complete them. If any alterations are made please notify us as they may or may not have effects on our data collection. The training plans provide structure for athletes' quality workout days. Athletes strength training, easy running pace and mileage, as well season structure is up to your guidance. We only ask that you ensure your athletes are treated uniformly across the two groups. Do not treat athletes in the control group any differently than the experimental

group. All factors across the groups should be kept the same in order for us to determine how the prescribed workouts affected their performance.

The two races should be conducted on a road or track. This will mitigate some weather differences that could have effects on the races. Please take care to keep all factors consistent between the two races. This includes but is not limited to, time of day, audience, order of event, timing system, gear choice, instruction of a race effort, nutrition, and of course race terrain.

Thank you for your participation in this event. We hope you and your team have an amazing season. Please contact us with any and all inquiries.

Appendix C: Pre-registration

Proposed study was pre-registered at OSF on April 28, 2023. https://osf.io/u6c9a/

Study Information:

Hypothesis:

Does focusing on reducing perceived effort at a given pace lead to an increase in performance/ decrease in injury/burnout risk when compared to more typical distance running training programs?

Design Plan:

Study Type:Experiment - A researcher randomly assigns treatments to study subjects, this includes field or lab experiments. This is also known as an intervention experiment and includes randomized controlled trials.

Blinding:

No blinding is involved in this study.

Study design:

This study will split the participants into experimental (psychobiological) and control (physiological) groups. Those groups will complete a 5k race before and after manipulation. The dependent variable is performance change between the two races. The independent variable is training over a four month period. This training will either be a focus on reducing perceived effort at a given pace (psychobiological), or focusing on increasing physiological indicators.

This study will determine if a greater percent change comes from focusing on physiological model or psychobiological model by manipulating PE at a given pace, while reducing overall intensity in the experimental group. Athletes will also fill out a questionnaire at the end of each week where they will report on training and indicate any signs of burnout or injury.

Data collection procedures:

Participants will include six collegiate cross country teams. Athletic administration and coaches will be informed about the effective and performance focused training their athletes will receive and thus be influenced to allow training alterations to their athletes. Athletes will also be given a pair of running shoes according to their group, which will incentivise their participation. Division will be ignored in favor of performance when recruiting participant teams. Teams previous year average time must be faster than 30:00 for 8k and 27:00 for 6k. These numbers were calculated by finding the median average team time for the mens and womens division 3 national cross country championships and then finding a time that is 87% as fast and then rounding to the closest 15 seconds. Most collegiate programs will be well under these time

cut-offs but including them is necessary to remove teams that do not have a highly trained distance running squad.

High performing distance runners are necessary to negate pacing inconsistencies over the 5-kilometer races and will make the results of the experiment more applicable to the distance running community. Athletes will be screened for pre-existing injuries and excluded from the experiment if indicating such injuries. The six teams will have athletes within each team randomly divided into control or experimental groups. A collegiate cross country team is made up of about 30 athletes, therefore the population size is estimated to be around 180.

The collegiate teams will be from the United States ideally from diverse environments. It should be noted that at minimum 3 out of the 6 teams should be located at sea level, or within 1,000ft of sea level. All other demographic traits will be ignored, as to ensure the applicability of the experiment's results to all the widest possible population of endurance athletes. Although conditions such as gender, sex, etc. should be noted and measured after the study has taken place in order to determine if any of these factors resulted in significant statistical differences.

Sample size:

6 college cross country teams of around 30 participants each, making for a total of n=180.

Manipulated variables:

The control/physiological model training group will use the Jack Daniel's 5k training plan as described in Daniels' Running Formula Third Edition (Daniels, 2014). Jack Daniel has a PHD in exercise physiology, has published multiple training books, and has coached multiple college and olympic distance running teams. His training formula is heavily based on physiological markers, specifically a VDOT score which is an altered version of an athlete's Vo2 max. Daniel's training

philosophy is based around the idea that an athlete's performance is influenced by six trainable factors. These factors include, the cardiovascular system, muscles ability to use oxygen, lactate threshold, Vo2 max, leg turnover, and running economy. The Daniels' running formula includes four phases of training. Each phase changes in prescribed paces and intensities of intervals (Daniels, 2014). Notably, psychological factors are not included as focuses in his training philosophy.

The experimental group/psychobiological group will take Daniels' running formula and make alterations to it that will result in a greater focus on psychological factors. In both training plans athletes are required to run intervals at certain paces based on their VDOT scores. In the experimental group all rest time between intervals will be multiplied by 1.5 and all continuous tempo runs will be changed to mile repeat sessions with 1 minute rest per mile. The increase in rest time will train the physiological system less effectively as the athlete will spend less time at the desired intensity. The increase in rest time will also decrease the perceived effort at a given pace. After the first races athletes or coaches will enter their times in a VDOT calculator. The calculator will give them their paces at different intensities. These paces are labeled at R, H, I, T, and E in the training plans below. R stands for repetitions and is the fastest pace. R pace feels almost like an all out sprint. H stands for hard and is a pace that athletes can hold for about 90 seconds. I stands for interval and is the main pace used for race pace intervals. T stands for threshold and is used for tempo runs. Lastly, E stands for easy and is run on non-workout days.

Athletes mileage and rest days between workouts are to be determined by their coaches. The coaches will be instructed to keep methods uniform over their entire team and report on general training philosophies that may be notable to the experiment.

Measured variables:

A 5-kilometer race was chosen as a measure for a multitude of reasons. Firstly, it is a largely aerobic event and thus applicable to endurance athletics. It is also the most common distance run in United States racing. Athletes will have already become very familiar with the event as it is the distance used in highschool cross country. It is also very common for cross country teams to use a within team 5k race to prepare for the season, as such this experiment will be little disturbance to the cross-country season.

The first of two 5-kilometer races will take place in August and the second in November. This is the approximate timeline for a collegiate cross-country season. The course run for the races can be individual to the individual teams but should be the same exact course run between the two races. The course should not include more than 100 ft of elevation gain or loss as to keep trial consistency between all measures. Because we are using percent change as a measure between two races it is acceptable that courses will not be exactly the same between different teams. Coaches should schedule the races to have as similar environmental conditions as possible. For example factors such as mud, rain, or extreme humidity could add a confounding variable as some athletes may thrive in certain conditions and perform differently based on environment rather than training manipulations. Coaches will report on the conditions of the races. The report should include temperature, humidity, and weather.

All other factors should be kept consistent between the two races. These include time of day, spectators, order of event, timing methods, footwear, external pacing methods, gps watches, competition heats, instruction, effort, and awards. It is important to note that the 5k race should be treated as a race and thus athletes should give 100% effort in both. This should not be an issue as cross country athletes are asked to do this 8-12 times a season.

At the end of every week during the study athletes will be required to complete a short questionnaire. The questionnaire will ask athletes to report on training to ensure that athletes are following the prescribed plan. Participants will be asked if they followed all prescribed workouts. If not they will be tasked with explaining how their training deviated from what was prescribed.

It will also ask about injuries and athletic burnout. The questionnaire will ask to report any significant injuries, running related or not. Athletes will be tasked to describe the injury in as much detail as possible. Injuries will be classified as training related or not. Any injuries that are overuse associated or originally occurring while running are training related. Injuries that occur due to a singular non-training related moment will be deemed non-training related. For example if an athlete breaks a toe because they dropped something heavy on it, that injury would be deemed non-training related and not factored into the analysis of the experiment.

To report burnout athletes will complete the Athlete Burnout Questionnaire. The ABQ measures three dimensions of athletic burnout, these include emotional and physical exhaustion, reduced sense of accomplishment. This questionnaire has been shown to accurately and reliably indicate endurance athletes who are or are not experiencing athletic burnout. (ABQ; Raedeke & Smith, 2001).

Statistical models:

Independent samples t-test as well as three regression analysis steps will be conducted to test the mediation hypothesis for each dependent variable.

Appendix D: Participant Questionnaire

Weekly Questionnaire: Fig 1.3

1. Have you experienced any injuries (running related or not) over the past week? If so please describe the injury, pain level on a scale of 1-10, cause of injury, other details on injury.
2. Have you followed your prescribed training plan? If not, then please describe any deviations in your training in relation to the prescribed training plan.
3. Athlete Burnout Questionnaire. Response is a 5-point Likert scale: 1-almost never, 2-rarely, 3-sometimes, 4-frequently, 5-almost always. Items 1 and 14 are reverse scored. RA-reduced accomplishment, E=emotionally or physically exhausted, D= devaluation.

Item	Subscale	Question
1	RA	I'm accomplishing many worthwhile things in running
2	E	I feel so tired from my training that I have trouble finding energy to do other things
3	D	The effort I spend in running would be better spend doing other things
4	E	I feel overly tired from my running participation
5	RA	I am not achieving much in running
6	D	I don't care as much about my running performance as I used to
7	RA	I am not performing up to my ability in running
8	E	I feel "wiped out" from running
9	D	I'm not into running like I used to be

10	E	I feel physically worn out from running
11	D	I feel less concerned about being successful in running than I used to
12	E	I am exhausted by the mental and physical demands of running
13	RA	It seems that no matter what I do, I don't perform as well as I used to
14	RA	I feel successful at running
15	D	I have negative feelings toward running

Appendix E: Training Plans

Fig. 1.3 Physiological/Control Training Group. Unaltered Jack Daniels Training Plan

Week	Workout 1	Workout 2	Workout 3
1	Long Run (20-25% of weekly mileage)	4x200R w/200jg+ 6x400R w/ 400jg+ 4x200R w/ 200jg	4x200R w/200jg+ 4x1T w/ 1 min rest+ 4x200R w/200jg
2	Long Run	6 sets of (200R x2 + 400R) 200jg+400jg	5x 1T w/ 1 min rest+4x200R w/ 200jg
3	Long Run	4x200R w/200jg+ 8x400R w/ 400jg+ 4x200R w/ 200jg	10x 2 min H w/ 1 min jog
4	Long Run	4x200R w/200jg+ 8x400R w/ 400jg+ 4x200R w/ 200jg	4x200R w/ 200jg+ 3T+ 2x1T w/ 1 min+4x200 w/ 200jg
5	Long Run	6 sets of (200R x2 + 400R) 200jg+400jg	6x 1T w/ 1 min rest+4x200R w/ 200jg

6	Long Run	12x400R w/ 400jg	2x 4H w/ 3min +3x3 min H w/ 2 min, + 2x2 min H w/ 1 min
7	Long Run	6x 1200I w/ 3 min	6x 1k I w/ 400jg
8	Long Run	3T+ 4x200R w/ 200jg+ 2T	6x 1k I w/ 400jg
9	Long Run	8x3 H 2min jg	5x1200I w/ 3 min jg
10	Long Run	3x2T w/ 2min +4x200R 2/ 200jg	5x1200I w/ 3 min jg
11	Long Run	7x3H w/ 2min jg	3T+4x200R w/ 200g+3T
12	Long Run	8x3H w/ 2 min jg	4x1 T w/ 1 min +2T
13	Long Run	6x4H w/ 3 min jg	3x2T w/ 2 min rest
14	Long Run	3T+1E+2T	6x4H w/ 3 min rest
15	Long Run (90 minute cap)	6x4H w/ 3 min jg	3x2T w/ 2 min rest
16	Long Run (90 minute cap)	3x1T 2min	**race 2**

Fig. 1.2 Psychobiological/experimental Training Group. Altered Jack Daniels Training Plan

Week	Workout 1	Workout 2	Workout 3
1	Long Run (20-25% of weekly mileage)	4x200R w/300jg+ 6x400R w/ 600jg+ 4x200R w/ 300jg	4x200R w/300jg+ 4x1T w/ 1.5 min rest+ 4x200R w/300jg
2	Long Run	6 sets of (200R x2 + 400R) 300jg+400jg	5x 1T w/ 1.5 min rest+4x200R w/300jg
3	Long Run	4x200R w/300jg+ 8x400R w/ 600jg+ 4x200R w/ 300jg	10x 2 min H w/ 1.5 min jog
4	Long Run	4x200R w/300jg+	4x200R w/ 300jg+

		8x400R w/ 600jg+ 4x200R w/ 300jg	3T+ 2x1T w/ 1.5 min+4x200 w/ 300jg
5	Long Run	6 sets of (200R x2 + 400R) 300jg+600jg	6x 1T w/ 1.5 min rest+4x200R w/ 300jg
6	Long Run	12x400R w/ 600jg	2x 4H w/ 4.5min +3x3 min H w/ 3 min, + 2x2 min H w/ 1.5 min
7	Long Run	6x 1200I w/ 4.5 min	6x 1k I w/ 600jg
8	Long Run	3T+ 4x200R w/ 300jg+ 2T	6x 1k I w/ 600jg
9	Long Run	8x3 H 3min jg	5x1200I w/ 4.5 min jg
10	Long Run	3x2T w/3min +4x200R 2/ 300jg	5x1200I w/ 4.5 min jg
11	Long Run	7x3H w/ 3min jg	3x 1T w/ 1 min +4x200R w/ 300g+3 x1T w/ 1 min
12	Long Run	8x3H w/ 3 min jg	4x1 T w/ 1.5 min +2x 1T w/ 1 min
13	Long Run	6x4H w/ 4.5 min jg	3x2T w/ 3 min rest
14	Long Run	3x1T w/ 1 min +1E+2x1T w/ 1 min	6x4H w/ 4.5 min rest
15	Long Run (90 minute cap)	6x4H w/ 4.5 min jg	3x2T w/ 3 min rest
16	Long Run (90 min)	3x1T 3min	**race 2**

Appendix F: Figures

Figure 1.0 Both Athletes are physically capable of running a five minute mile. Athlete A runs 95% of physical limit, resulting in a 5:15 mile time. Athlete B runs a 90% of physical limit resulting in 5:30 mile time.

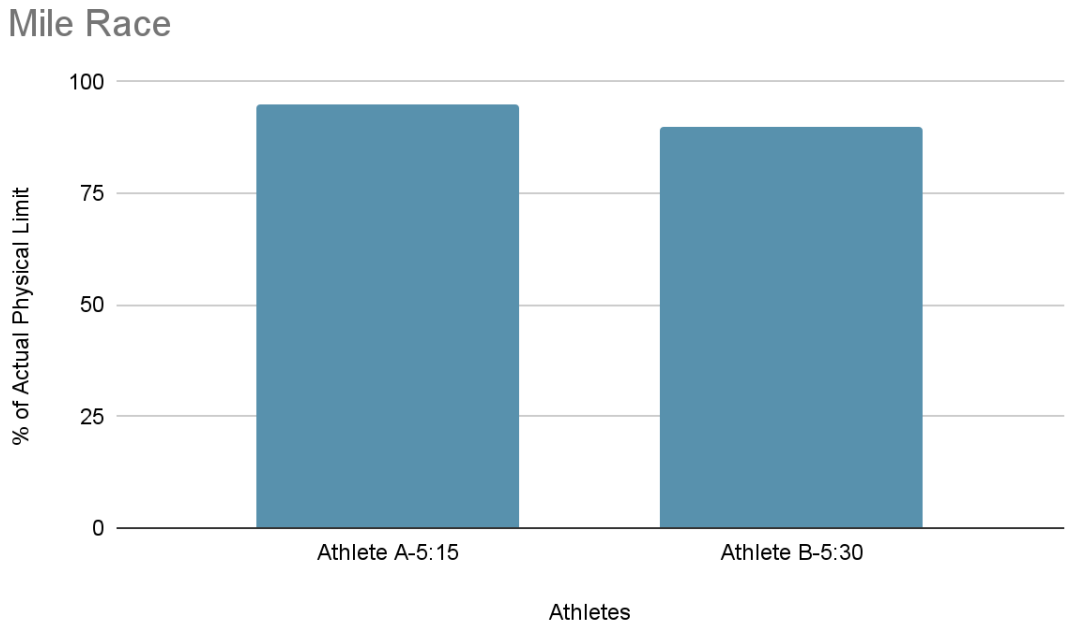


Fig 1.4 represents predicted results. Both groups would run an average of 15:30 in the first race. In the second race the experimental group would improve to an average time of 14:30 while the control group would improve to an average time of 15:15.

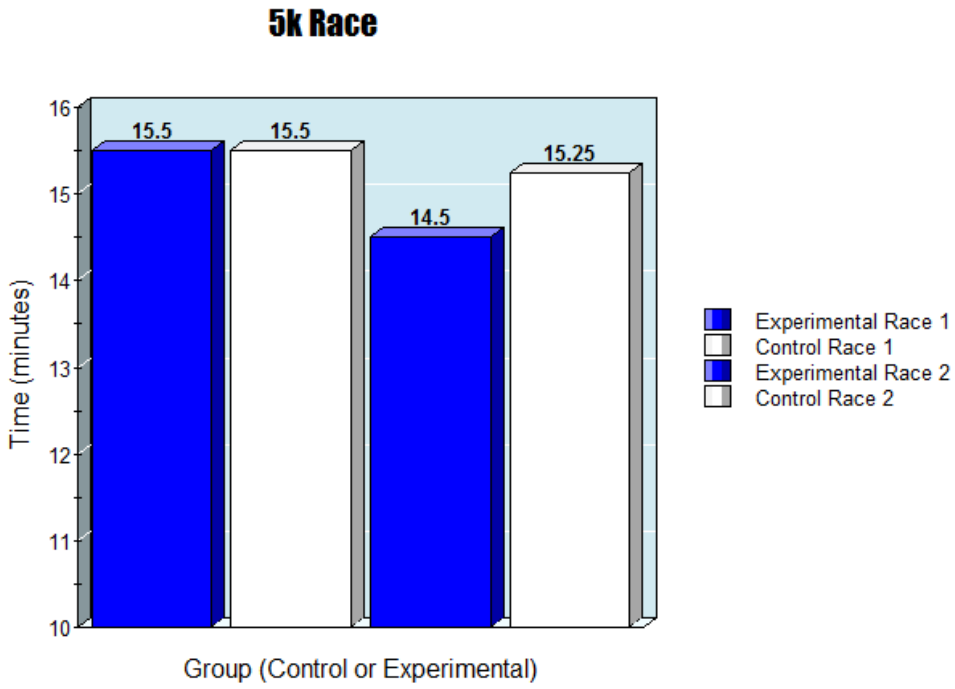


Figure 1.5 represents predicted result that includes 15 training related injuries reported by the experimental group and 44 training related injuries reported by the control group.

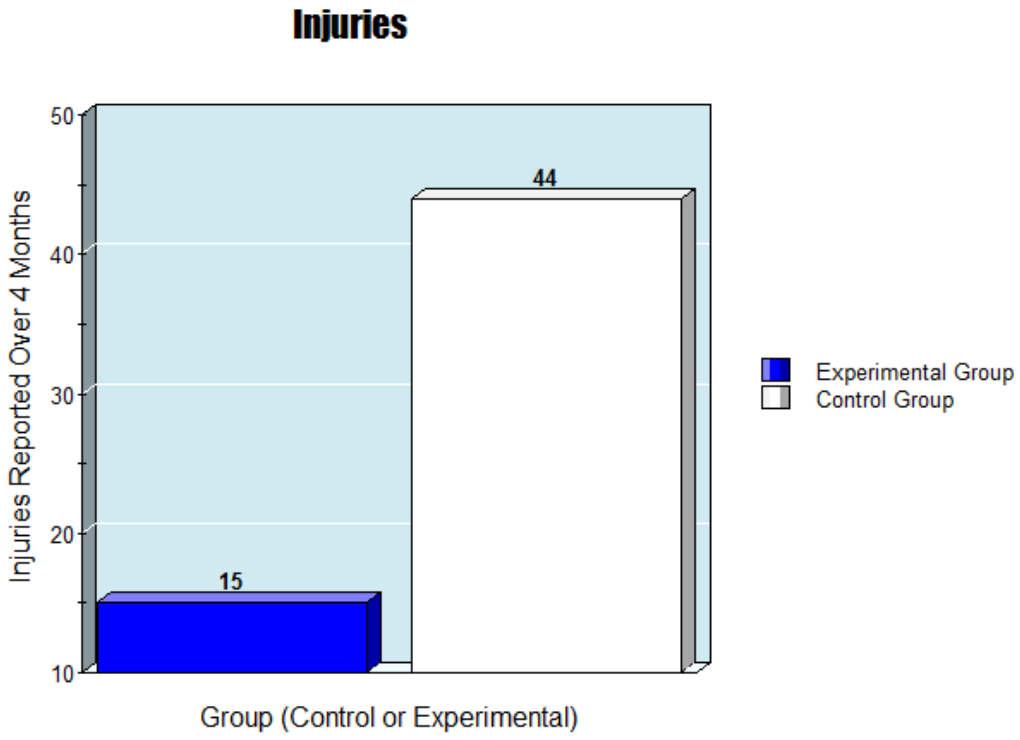


Figure 1.6 represents predicted result that includes 9 reports of athletic burnout by the experimental group and 45 reports of athletic burnout by the control group.

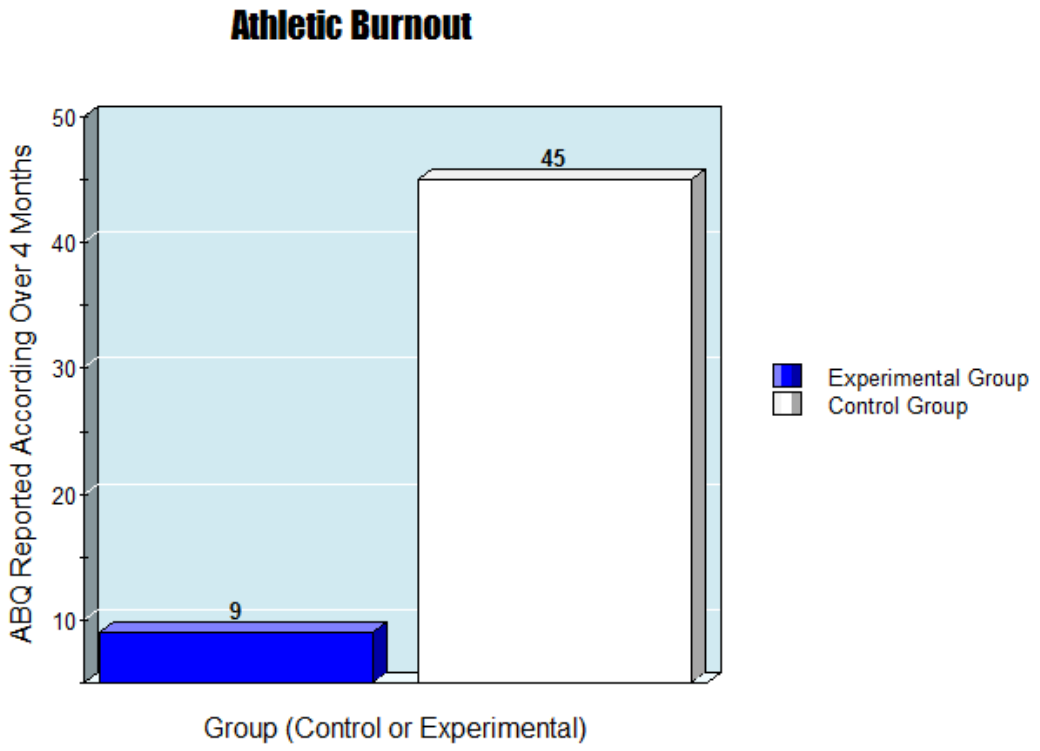


Fig. 1.7 Mediation Analysis