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ASSESSMENT OF DEMOGRAPHIC, ANTHROPOMETRIC, AND PHYSICAL PERFORMANCE VARIABLES AS PREDICTORS OF SPRINT CYCLING POWER

JAMES MELLEN
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Reviewed and approved* by the following:

Giampietro Vairo
Clinical Assistant Professor; Program Director: Clinical Education Coordinator, Athletic Training Major
Thesis Supervisor

Jian Yang
Professor of Biomedical Engineering
Honors Adviser

William Hancock
Professor of Biomedical Engineering
Faculty Reader

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

Prior research suggests peak sprint power (PSP) is correlated with cycling sprint times, indicating that individuals able to produce higher PSP demonstrate faster ride times. These faster ride times are indicative of better performance in sprint cycling competitions. **PURPOSE:** The primary aim of the study was to determine if a vertical jump height (VJH) test and other anthropometric and demographic measures could model sprint cycling power. It was hypothesized that a higher VJH would correlate with a higher PSP. **METHODS:** Trained cyclists were enrolled in the study and completed a series of VJH tests, PSP tests, and provided demographic and anthropometric data. Multiple regression examined the predictors of normalized peak sprint power (NPSP). PSP was normalized by taking the PSP and dividing by the subject's mass. **RESULTS:** The average normalized PSP the subjects produced (15.5 ± 3.1 watt/kg) and average VJH (37.4 ± 7.5 cm). There was a significant positive association between VJH, average VJH velocity, and NPSP (r^2 = 49.24%). **CONCLUSION:** The results indicate that a higher VJH will indicate that a cyclist will have a higher normalized PSP.

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Chapter 1

Introduction

Track Cycling- Background

Track cycling has been an Olympic event since the Olympics in 1896 in Athens, Greece which was the first modern Olympic games in modern history (1). Since 1924 there has always been some event denoted as a sprint type event. In track cycling, sprint events are very short and explosive races that require immense power and speed on the bike. Most recently, at the 2016 Olympic Games in Rio de Janeiro, Brazil, the track cycling events included the team sprint, team pursuit, omnium, keirin, and the individual sprint for both men and women. Out of these five events, the team sprint, keirin, and individual sprint are of the sprint discipline.

These three races for both men and women gives each country an opportunity to win six gold medals coming from the sprint discipline of track cycling alone. Looking ahead to the 2020 Olympics in Tokyo, Japan, these same three sprint events will be contested again, so another six medals will be up for contention.

Track Cycling- Sprint Racing Explained

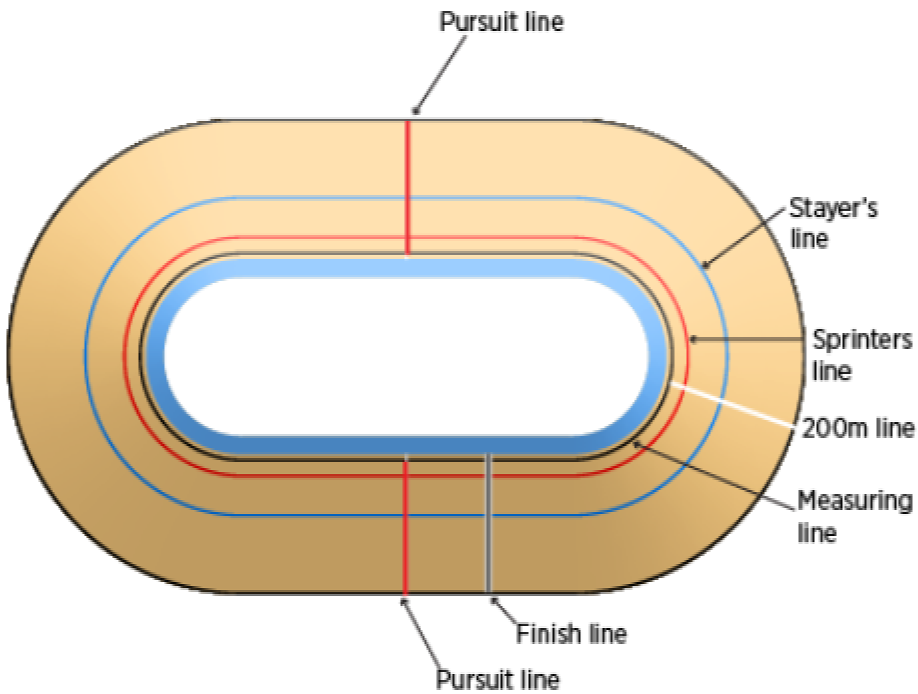

Figure 1: Diagram of a standard 250-meter velodrome. Figure taken from: Fulton (2)

Team sprint consists of three riders for men and two riders for women. The riders line up at the pursuit line on the track side by side. When the countdown timer has reached zero it is an all-out sprint. The first rider will lead the first lap and then moves out of the way for the second rider to lead the second lap. In the women's version of the race, the clock stops when the second rider crosses the pursuit line on the second lap. For men, the clock stops when the third rider reaches the pursuit line on the third lap. The current world record for the men is 41.871 seconds set by a German team in 2013 (3) while the current world record for the women is 31.928 seconds set by a Chinese team in 2016 (4).

The keirin and individual sprint are both individual events. In a keirin race, six riders are led up to speed by a motor bike which gradually increases its speed to 50 kph for men and 45 kph for women (5) over the course of three laps. After the riders have been paced up to speed, the motor bike pulls off of the track to allow the riders an all-out sprint for three laps.

The individual sprint is composed of races of two riders facing each other, one on one, and progressing through a bracket. The race consists of only three laps (750m). The riders are placed in the initial seeding bracket by competing in a 200-meter time trial. This time trial allows riders to gain as much speed before the line, which is called a flying start. The time is taken from the 200-meter line to the finish line. Currently, the world record in this event for men is 9.347 seconds set by Francois Pervis in 2013 (6) and 10.384 seconds set by Kristina Vogel in 2013 (7).

The distance and duration of these events makes them predisposed to an individual specializing in sprint. Since the races are so short they require maximal effort for a very short period, in some cases less than ten seconds, but in almost all cases less than a minute. Physiologically this will rely heavily on the anaerobic system versus the aerobic system to produce much of the energy required for the sprint disciplines.

Vertical Jump-Height and Sprint Times

Although track cycling accounts for ten gold medals in the Olympic Games, not as much research has gone into cycling as into sprint performance in running. Since much of the research has been done on running, much of the basis of this research will come from previous research looking at performance of sprint running.

In a study done by Marques et al., he analyzes vertical jump height relationship to ten-meter sprint times in running (8). Using a linear encoder device to measure the parameters of the vertical jump, they tested a large sample of trained athletes. After testing, they found that there were associations between ten-meter sprint times and peak velocity of the vertical jump. They also found that there were nonsignificant relationships between ten-meter sprint times and force of the vertical jump. This research also highlights the gaps in literature where many studies look at isometric and isokinetic tests that predict sprint times. The research argues that these do not take into account all of the muscles needed in sprinting which must be working together simultaneously. The main difference is that in order to predict sprint performance you must be measuring a dynamic activity. This study also uses a much shorter distance for measuring sprint times than other studies in the literature. In Marques' et al study, the average sprint time was only 2.03 seconds. This translates well to cycling performance because during sprint type power tests, the subjects usually hit peak power within the first or second pedal stroke which will usually take less than a second.

Vertical jump height has also been shown to have a positive relationship to higher running powers. In the study conducted by Davis et al., a cohort of physically active subjects was recruited to do a vertical jump test, broad jump test, and a ten and forty-yard sprint (9). The sprint time was factored in with body mass to give an average power over the ten yards and forty yards. When they ran the statistical analysis on these parameters they found that the vertical jump height was positively associated with a higher ten-yard power. In the case of this research study, calculating the ten-yard power normalizes the time to body weight. This would be more like comparing vertical jump height to non-normalized peak sprint power on the bike. This research also found that a greater distance long jump would be indicative of a faster forty-yard sprint time. A long jump test makes sense to do for a running sprint time, since much of the force needed by the muscles is used to accelerate in a forward direction. On the other hand, on the bike, this force is needed to go straight into the pedals, so a vertical jump would most likely be a better test.

Loturco et al. looked at the progression of vertical jump heights as a group of Parapan American Game athletes prepared for the Pan Am Games in 2015 (10). In particular, this study looked at loaded and unloaded squat jumps association with in competition 100 and 200-meter dash times. A squat jump is when the subject squats down to a knee flexion angle; where the thigh is perpendicular to the ground and then the subject jumps up. This method of vertical jump is a bit different from a typical vertical jump that is normally performed. In the study, they put these measures into a multiple regression model and were able to come up with a model that was representative of 66% of the population that was tested. This regression model shows that by using a combination of weighted and unweighted squat jumps, a 100- and 200-meter dash time could be calculated with reasonable accuracy.

Essentially, each of these studies agree that various forms of vertical jump tests are good predictors of a lower sprint time in running. While running, like cycling, does use the lower extremities, the firing patterns and muscles used in running and cycling are very different. Only one study has been done linking vertical jump height to peak sprint power. Stone's et al. study looked at a large number of variables, including maximal strength, coaches rank, power tests from the vertical jump test, and sprint cycle power tests. According to Stone, there was strong correlation between vertical jump height, which was a peak power exercise, and peak power measured on the bike, using a Wingate Protocol. The methods of the Wingate Protocol, done in this study, will be discussed in a future section (11).

Power Measurement in Cycling

In the sport of sprint running, power must be derived from taking the velocity over the entire course of running and dividing by body mass and multiplying this by a conversion constant (sprint power (w) = running velocity (m/s)/mass of subject (kg) * 9.80665 kg/m/s) (10). The discipline of sprint cycling has methods of directly measuring the power output that a cyclist puts into the pedals, instead of calculating it in a roundabout way.

The way that power is typically measure on a bicycle, is taking the power for each revolution of the pedals. This is done by measuring the force that is being put into the pedals and then multiplying it by the velocity of the pedals. The velocity of the pedals is determined by taking the radius of the crank arms (which is anywhere from 160mm to 180mm), finding the circumference of the circle that the cranks make, and multiplying this by the rotations per minute of the pedals. (power = force on pedals (N) *velocity of pedals (m/s)).

When reading literature on bicycle power outputs, it can be confusing as to which peak power the studies are talking about. There are three main ways of measuring peak power. The first is to take *absolute instantaneous power*. This is measured at as small a time interval during the pedal stroke as possible. Because most individuals do not put consistent force into the pedals, this power will vary drastically as the pedal stroke is completed. This will also lead to higher peak power values since the power varies so much during the pedal stroke. This can be seen in *Figure 2* from Martin's et al. study, as the oscillating line that peaks between 2000 and 2500 watts and dips from 0 to 500 watts (12). In many cases, consumer power meter devices do not give this kind of data, so this method of peak power measurement is not used in most studies. The other main way to measure peak power, is to take *pedal revolution averaged power* (the average over one pedal stroke). This still measures at the same sampling rate as when calculating absolute instantaneous power, but it only requires one device to measure the rotations per minute of the cranks. This is shown by the line with dots in *Figure 2*. Comparing the absolute instantaneous power and the pedal revolution averaged power, the pedal revolution averaged power has lower absolute values than the instantaneous power. The last way that power is typically presented is by taking the *one second average of the power*. Again, this method samples the rate the same as when calculating the absolute instantaneous peak power but instead averages the power values for one second. This is by far the most common form that power is presented. In all consumer power meters, the devices only show the power as a one second averaged power.

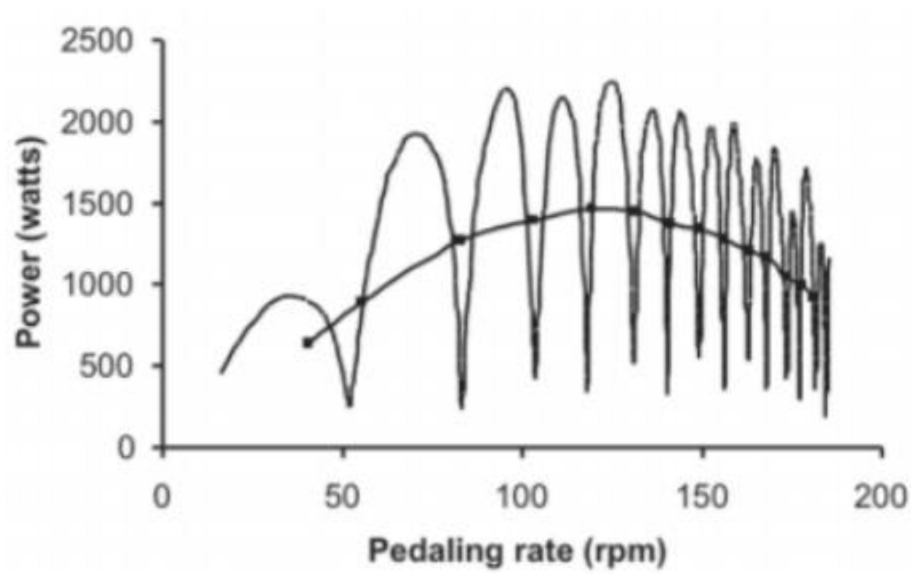

Figure 2: Shows absolute instantaneous power and averaged power plots relationship with each other. Figure taken from Martin et al. (12)

Power Measurement in Predicting Sprint Times

Power is a great tool to track training changes and adaptations, but it is not always a good predictor of sprint performance in the discipline of track cycling. In sprint cycling the power that an individual puts out goes into two main areas. These are acceleration and overcoming the aerodynamic drag that they produce by moving through the air.

A study conducted by Martin et al., looked at modeling and predicting sprint times using field derived parameters (13). These included the two main categories of aerodynamic drag and acceleration. They came up with a method to derive aerodynamic parameters in the field instead of going into a wind tunnel. Using this and measured peak powers, they were able to accurately predict sprint times with an accuracy that represented 98.9% of the population tested.

A critical part of their study was the mass of the cyclist and equipment. Since most sprint bikes weigh approximately the same, the main differentiator is body mass of the subjects. Extrapolating out this data means that a person whose mass is 80 kg and able to produce 1500 watts of peak power, will be able to go faster than an individual whose mass is 90 kg and can also produce 1500 watts of power. This fundamentally makes sense because essentially the power output is a measure of force being put into the pedals over a certain time. With a lesser mass, an individual will be able to have a greater acceleration, and therefore lower final time, if the power is kept constant. This is why in many studies, power is normalized to body mass so the normalize sprint peak power value can be accurately calculated.

Definition of The Study

The primary goal of this study is to assess demographic, anthropometric, and physical performance variables to determine if any of these are predictors of normalized peak sprint power would be a predictor of sprint cycle performance. The demographic variables collected were age and sex. The anthropometric variables collected were mass, height, and mid-thigh circumference.

Two kinds of physical performance variables were also collected. These included variables from the vertical jump test such as height, average force, peak force, average power, peak power, average velocity, peak velocity, average acceleration, peak acceleration, total work, total time, time of the concentric movement, and time of the eccentric movement. All of these variables were computed using the PUSH band. The other physical performance variable that was collected was the sprint cycle power test. The variables that were collected were peak power, average power, peak RPM, and average RPM using a Wattbike Cycle Ergometer.

While all these variables were collected, the primary of the goal of the study was to create a simple model that would predict normalized peak sprint power. Ideally, this simple model could be used inexpensively by a wide variety of people with varying skill levels.

Application of the Study

The possibility of six gold medals available in the Olympics puts a high emphasis on obtaining the best athletes to compete and providing the best training techniques available in the discipline of track cycling. Talent identification is one area that is critical in the discipline of sprint cycling. According to Eynon’s work, there is a significant difference in a particular genotype of sprinters versus endurance athletes (14). This work highlights that in a talent identification process it may be possible to identify individuals that are more predisposed to sprinting and in likelihood will have better success in the discipline of sprint cycling. While genetic testing cannot be used for all prospective athletes of a program, a simple physical test can be implemented to identify athletes that may be able to succeed in the sprint cycling discipline. For example, hundreds of individuals may be able to first complete a simple physical test. Then, the most promising individuals that performed well on the simple test could move onto a more in-depth testing protocol with more data and more analysis.

Another important application of this study was to give coaches and athletes a tool to gauge normalized peak sprint power without needing to use an expensive power measuring device. During the training process it is vital to know how athletes are responding to training. A simple test could help coaches and athletes determine if the training plan that they are pursuing at the time is working effectively or not. This could also help athletes and coaches determine if the athlete is ready to perform his/her daily workout by adding this simple test to the warm-up procedure. If the athlete does not hit a defined target in the test, it could indicate that they are too fatigued to complete the workout effectively and should take another day of rest. If done correctly, this method of testing and training could help to prevent fatigue and overtraining.

Lastly, this study was looking to see a more direct relationship between vertical jump height and sprint power. In the sport of running, there are no direct power measurement devices, so only the vertical jump height and running sprint times can be correlated. On the other hand, cycling has devices that can directly measure the power output of an individual. This direct measurement can better isolate many variables that could affect an actual physical performance rather than looking at sprint times only.

Chapter 2

Methods

Overview

The primary aim of this study is to provide a simple test that can predict normalized peak sprint power on the bike. In order to do this demographic, anthropometric, and physical performance variables will be collected and analyzed to see if they are able to accurately predict normalized peak sprint power. The demographic information that will be collected will be sex, age, and cyclist experience level. Anthropometric measures will include height, mass, and mid-thigh circumference. Lastly, the physical performance variables that will be collected will consist of the vertical jump test and the "on the bike" sprint power test. Several parameters from each of these will be collected and discussed in a later section.

The testing protocol consisted of four phases. The first being a survey and measurement of the anthropometrics, second a warmup, third the vertical jump tests, and lastly the "on the bike" sprint power tests.

The data collected was then checked for statistical significance and put into a multiple regression model. Several models could be made depending on the complexity of the model required.

Inclusion and Exclusion Criteria

Since the primary aim of this project was to produce a broadly applicable simple test to predict normalized peak sprint power there was a large inclusion protocol. This study looked for individuals between the ages of 13-65 of either sex that are English speakers. This allowed the study to be broadly applicable to a larger population. The subjects needed to be English speakers in order to conform to the Internal Review Board protocol.

One area that was important in the inclusion criteria was that individuals needed to have at least one year of cycling experience. Practically, this could range anywhere from being a recreational rider to an elite level sprinter. The goal of this criteria was to keep the study applicable to cyclists. If a person who had never been a cyclist before could participate in the study, this could skew the data because of their inability to correctly pedal a bike. Cyclists with at least one year of experience would have the necessary skills that are required in doing an "all-out effort" on an ergometer so their power could be accurately measured.

The main exclusion protocol was to verify that subjects were healthy and able to perform the physical tests required by the study. The exclusion criteria is as follows:

1. Currently experiencing pain, numbness or paresthesia in the lower back or lower extremities

2. Significant self-reported orthopedic injury of the lower back or lower extremity within the past 1 year

for e.g. disc herniation, fracture, ligamentous sprain etc.

3. Significant low back or lower extremity surgery within the last 1 year for e.g. ACL reconstruction, hip arthroscopy, lumbar laminectomy etc.

4. Currently under the care of a physician or seeking rehabilitation for a lower extremity or low back

injury or pain

5. Have had a head trauma, concussion or were cognitively impaired within the past 6 months

6. Currently experiencing any concussion like symptoms such as nausea, dizziness, headache etc.

7. Neurological conditions e.g. stroke, Parkinson's disease etc.

The inclusion and exclusion criteria were assessed in a prescreening survey before the subjects were enrolled in the study. If subjects did not meet the inclusion and exclusion criteria they were not allowed to participate in the study.

Recruitment

The testing for this project was done in the Lehigh Valley so subjects were enrolled from and around that area. The Lehigh Valley is a hot bed for cycling because it is home to the Valley Preferred Cycling Center (Lehigh Valley Velodrome). In the summer months the Lehigh Valley attracts world class cyclists from a variety of nations including but not limited to New Zealand, Australia, Great Britain, South Africa, Canada, Venezuela, Japan, and the Netherlands. Many of these countries send their national teams to compete at events in the Lehigh Valley that will qualify them for World Cups and World Championships which ultimately lead to the Olympic Games. This study aimed to attract as many of these high-level athletes as possible.

The researcher used flyers and mass email to recruit subjects into the study. The goal of the study was to recruit at least 30 participants so that the study was able to meet many assumptions of a large sample size for statistical purposes. Having at least 30 participants would also give better and more generalizable data.

Phase 1- Demographic and Anthropometric Measures

The demographic portion of this phase of the study consisted of filling out a demographic survey. Simply, the participants identified their age and sex. These were entered into a Google Form for ease of data recording and processing.

The participants were also asked to rank themselves on a Cyclist Experience Level Scale. This scale was designed to qualify the experience level of the cyclist at the time of the testing. The scale that was presented to the participants is as follows:

Table 1: Cyclist experience level scale

Cyclist Experience Level Scale	
Level	Description
World Class (Level 1)	Competed at Olympic Games, World Championships, or World Cups
National (Level 2)	Competed in respective countries National Championships
State (Level 3)	Racing history at a state level
Recreational (Level 4)	No racing history

The anthropometric measures for this study consisted of measuring body mass, body height, and mid-thigh circumference. The participants were asked to step onto a Detecto Physician's Scale to be measured and massed. The height of the participant was recorded in centimeters and the mass of the participant was recorded in kilograms.

The mid-thigh circumference was taken using standard anthropometric measurement techniques outlined in literature. The greater trochanter and lateral femoral epicondyle were located. This distance was taken and cut in half. At this halfway mark the circumference of the thigh was taken (15).

Figure 3: Measuring mid-thigh circumference from midway between the greater trochanter and lateral femoral epicondyle. Figure taken from: Caines (16)

Phase 2- Warmup

The warm-up procedure of this study was focused on having the participants move to warm their muscles while not fatiguing them. Since the Wattbike cycle ergometer was being used for testing, this was the device used for the participants' warm-up. The total time for the warm-up procedure was ten minutes. It started with rolling at 50 watts (measured by the Wattbike cycle ergometer) for the first five minutes. In the next two and a half minutes, the pace was increased to 75 watts. The last two and a half minutes were completed at 100 watts. This warmed the subjects' muscles so they were in a good physiological state to complete the rest of the testing.

Phase 3- Vertical Jump Tests

After three minutes of rest after completing the warm-up, the subjects would move onto the vertical jump portion of the test. In order to familiarize the subjects with the test they were allowed one practice jump. To perform the jump, the subjects stood on flat ground. They kept their hands on their hips for the entire duration of the jump. The stance of the vertical jump can be seen in *Figure 4* below. This method was selected to try to eliminate any extra upward force that is created when using the arms in a vertical jump. By keeping their hands on their hips this would allow for a better measure of the lower body rather than a combination of lower and upper body. This same method was used in Marques et al. study when their cohort of subjects performed the vertical jump (17). The only other instructions were for the subjects to jump as high as they could.

Figure 4: Subject performing a vertical jump with the PUSH Band. Figure taken from PUSH (18)

The height and other parameters of the vertical jump were recorded with a PUSH band. This is an accelerometer-based system used to measure displacement, velocity, acceleration, force, and power. This device is worn on an elastic strap that wraps tightly around an individual's torso. Care was taken to be sure that the device was properly secured to the subjects to be sure that noise measured by the accelerometers would not corrupt the data. The PUSH band interfaces through Bluetooth with an iPad or iPhone where the data is recorded and can be analyzed. To perform the vertical jump test, the subjects were guided by the instructions on the PUSH app. This gave a five second countdown before it instructed the subjects to jump and began measuring the height of the jump.

Three minutes rest was given between each of the vertical jumps. The second jump done by the subjects was completed in the same manner as the first with no changes to the protocol. The data that was collected from the PUSH band was vertical jump height (cm), average force (N), peak force (N), average power (watt), peak power (watt), average velocity (m/s), peak velocity (m/s), average acceleration (m/s/s), peak acceleration (m/s/s), total work (J), rep duration (s), rep duration in the concentric phase (s), and rep duration in the eccentric phase (s). Not all of these variables will be used in all analyses but they were still recorded and saved in the data bank.

Phase 4- Wattbike Cycle Ergometer Testing

After completing the two-vertical jump height tests the subjects moved onto the Wattbike cycle ergometer testing. The Wattbike cycle ergometer is a standard ergometer than can be adjusted to match a variety of cycling positions and body types. The seat height can move up and down and fore and aft to adjust for the proper position of the legs. The handle bars are also able to adjust up and down and fore and aft to adjust for the proper body position. The goal of fitting the subjects was to set the Wattbike cycle ergometer up in a way that matched the way their normal bike fit them. The seat height was recorded for each of the subjects. Also, the standard shoes that they would use for cycling were used in the power tests. By doing this the individual's foot position would be in exactly the same position as when they are riding their personal bike because the cleats on the bottom of their shoes would be adjusted in the same way.

Once the Wattbike cycle ergometer was adjusted to the proper fit for each subject the testing protocol for the power tests could commence. Two power tests were performed for each subject. One power test consisted of an all-out six second test. The subjects were told to put maximal effort and force into the pedals once the test was underway and continue to do this until the test finished. The Wattbike cycle ergometer screen gave a five second countdown before the power test. When this countdown reached zero the subjects began the six second test. Each subject either chose to start on their right or left foot. This decision was recorded. To start, the pedals were oriented in a 10 o'clock and 4 o'clock position with whichever foot that was chosen to start on in the 10 o'clock position.

The Wattbike cycle ergometers have two resistance adjustments. One allows more wind into the turbine to create more resistance on the pedals and the other applies a magnetic braking system to apply resistance. The first test was completed on a level 1 (of 10 levels) for the wind resistance and a level 1 (of 7 levels) for the magnetic resistance. The second six second power test was completed on a level 5 for the wind resistance and a level 1 for the magnetic resistance.

This method of having two different resistances for the separate power tests was designed to be able to assess peak powers at different resistance loads. Since power is so dependent on the RPM that a cyclist is hitting, different cyclists of different abilities are able to hit a higher peak power at varying resistances. By varying the resistance, a broader scope of peak powers was able to be found while keeping the testing consistent so that the subjects' results could be compared amongst each other.

The second test was completed five minutes after the first test on the Wattbike cycle ergometer. This allowed enough time for the subjects to recover between efforts so they were able to put maximal effort into the second test. From both the first and second test, the peak power (watt), average power (watt), peak RPM (RPM), and average RPM (RPM) were recorded and saved.

Validation of the PUSH Band

The PUSH band has been validated to provide accurate data internally by the company that makes the band and externally by peer reviewed sources. In the internal validation the PUSH band is compared with the Gymaware which is a linear position tracker. These tests were validated against various exercises performed which used a barbell. The results showed that the PUSH band was able to predict bar velocities with close similarity to the linear position tracker (19).

The external validation was done by Balsalobre et al. This study compared the PUSH band to a T-Force linear transducer in measuring back squat on a Smith Machine (20). The results showed high correlation between the linear transducer and the PUSH band. The research also says that they showed almost equal reliability.

Validation of the Wattbike Cycle Ergometer

There are several sources of literature that validate the Wattbike cycle ergometer as being a reliable means of measuring on-the-bike power. The study done by Hopker et al. compares the Wattbike cycle ergometer power measurements to an SRM power meter measurements. The SRM is considered a very accurate consumer power measurement device. He suggests that "when compared to the SRM, the Wattbike has acceptable accuracy" (21).

Another study done by Driller et. al looked at the reliability of a Wattbike cycle ergometer's accuracy in a 30 second sprint power test of trained cyclists. This study validated both power and RPM. They concluded that when looking at a 30 second sprint power test, the Wattbike cycle ergometer can produce highly repeatable and reliable results (22).

Statistical Analysis

When collecting the data there were two sets of vertical jump data points. These respective variables were averaged together to make one average vertical jump data set. This helped to make the data set simpler and easier to manage. A similar process was done with the two Wattbike sprint power tests. Both of these tests were averaged together to give one set of power numbers for each subject.

Once the data is collected and organized, each data set is tested to see if it is normally distributed. If it is normally distributed, the data meets the assumptions needed to continue the analysis.

Lastly, the data was put into a multiple regression to choose the most representative model. Along with the multiple variable regression, an adjusted R-squared was calculated to see how well the model predicts normalized peak sprint power.

Chapter 3

Results

Subjects- Cyclist Experience Level

After collecting the data for self-reported cyclist experience level, it was determined that this was not a good measure of the actual level of a cyclist. Since this was a rating scale designed to be rated by the individuals themselves, this caused error in the ratings. For example, one of the measures was if the subjects competed at their country's national championships. For the subjects this could mean the entire spectrum of national championships (junior, elite, and masters) all of which have very different skill levels associated with them. Due to this fact the measure was not included in the analysis. However, the data that was collected indicated a range covering the entire cyclist experience level (from 1 to 4) and having a mean of 2.53 with a standard deviation of 1.14. This study tested individuals who had never raced competitively and those that were the current World Champion.

Subjects Results- Demographics

Among the 32 subjects that were used for the study, 8 of the subjects were female and the remaining 24 were male. The mean age of the subjects was 26.5 years with a standard deviation plus or minus 14.6 years. The youngest subject that was tested was 14 years of age. The oldest subject that was tested was 64 years of age. This information is summarized in *Table 2*.

Subjects Results- Anthropometrics

The first anthropometric data that was collected was the height of the subjects. The mean height for the cohort was 174.6 centimeters with a standard deviation plus or minus 8.3 centimeters. The tallest subject was 193 centimeters and the shortest subject was 156.5 centimeters. The mean mass of the subjects was 75.2 kilograms with a standard deviation of plus or minus 12.7 kilograms. The subject that massed the most was 104.3 kilograms and the subject whose mass was the least was 54.9 kilograms. The last anthropometric measure that was collected was mid-thigh circumference. This mid-thigh circumference mean was 57.0 centimeters with a standard deviation of plus or minus 5.3 centimeters. The largest thigh circumference was 68.9 centimeters and the smallest thigh circumference was 46.0 centimeters. This data along with the demographic data is summarized in *Table 2* below.

Table 2: Demographic and Anthropometric Metric data

Category	**Average**	**Standard Deviation**	**Maximum**	**Minimum**
Age (years)	27	14.6	64	14
Height (cm)	175	8.3	193	157
Mass (kg)	75	12.7	104	55
Mid-thigh Circumference	57	5.3	69	46

Tests Results- Vertical Jump Test

As the subjects completed the vertical jump tests the parameters of vertical jump height (cm), average force (N), peak force (N), average power (watt), peak power (watt), average velocity (m/s), peak velocity (m/s), average acceleration (m/s/s), peak acceleration (m/s/s), total work (J), rep duration (s), rep duration in the concentric phase (s), and rep duration in the eccentric phase (s) were collected using the PUSH band. Since two vertical jumps were completed, the average of each of the respective metrics was taken for each subject. This would allow easier data processing further in the analysis and provide a bit more reliability in the reproducibility of the vertical jumps that the subjects completed. Once piece of interesting information that was obtained from the first versus the second jump was that on average, subjects jumped approximately two centimeters higher on the second jump when compared with the first.

The main piece of information to pull from this set of data is the vertical jump height. The average of all of the subjects was 37.36 centimeters with a standard deviation of plus or minus 7.54 centimeters. The highest that a subject jumped was 47.67 centimeters and the minimum was 22.01 centimeters.

Table 3: Vertical Jump data from the PUSH Band

	Average	**Standard Deviation**	**Maximum**	**Minimum**
Vertical Jump Height (cm)	37.4	7.54	47.7	22.0
Average Force(N)	1423	426	3473	1033
Peak Force(N)	1623	477	3913	1180
Average Power (w)	1713	553.3	3813	1003
Peak Power(w)	2724	1013.3	7283	1564
Average Velocity(m/s)	1.35	0.17	1.71	0.99
Peak Velocity(m/s)	2.69	0.28	3.06	2.07
Average Acceleration(m/s/s)	8.71	2.10	14.10	5.16
Peak Acceleration (m/s/s)	11.3	2.7	19.6	6.6
Total Work(J)	379	149	989	145

Rep Duration (s)	1.64	0.23	2.04	1.05
Rep Duration Concentric (s)	1.09	0.22	1.48	0.44
Rep Duration Eccentric (s)	0.55	0.06	0.62	0.42

Tests Results- Wattbike Cycle Ergometer Test

The Wattbike test also consisted of two separate tests. This was slightly different than the vertical jump test because one of the tests had a higher resistance than the other bike test. Even though they were different loads, the two tests were averaged together since each subject performed both tests at the same varying resistance.

Looking at the two tests separately, on average the subjects were able to put out 50 more watts on the higher resistance setting compared to the lower resistance. Their average power was also significantly higher with the higher resistance. This difference was approximately 200 watts on average. This large difference in average wattage makes sense because with the lower resistance, once the inertia of the Wattbike is overcome, there is not much resistance. Since the higher resistance is added through wind, the faster a subject pedals, the more resistance they will feel, and so it is not surprising that this average wattage of the higher resistance is so much higher.

The seat height (seat height number on the Wattbike), peak power (watt), average power (watt), peak cadence (RPM), and average cadence (RPM) were all measured for both the high and low resistance right or left starting foot. The powers and cadences were then averaged together from the high and low tests to form one single peak and average power and cadence for each subject. This data is presented in *Table 4* below.

Thirteen (13) of the subjects started with their right foot while the remaining eighteen (18) started with their left foot. Most notable the peak power average of the subjects was 1157.2 watts with a standard deviation of plus or minus 280 watts. The most power that a subject produced was 1776.5 watts and the least power that a subject produced was 648.5 watts.

Table 4: Results from the Wattbike Cycle Ergometer

	Average	Standard Deviation	Maximum	Minimum
Seat Height	13	3.8	21	7
Peak Power (watt)	1157	280	1777	649
Average Power (watt)	882	185	1269	475
Peak Cadence (RPM)	162	13	187	127
Average Cadence (RPM)	152	13	175	118

Normalizing Peak Sprint Power

Since peak power is an arbitrary number when it comes to predicting sprint times it was determined it would be best to normalize it to body mass (weight). Essentially, the power measured on the bike is the amount of energy an individual is able to put into the pedals over a certain amount of time. This energy is then divided into accelerating their mass and overcoming the wind resistance that they create. According to Martin (13) this aerodynamic profile can be estimated among cyclists and does not change drastically. What does change, however, is the mass of the cyclist. The less mass, the faster they are able to accelerate and the faster time they will ride. Therefore, for this study, power is normalized to body mass. Normalized peak sprint power is also the variable that has been used in predicting sprint times. A higher normalized peak sprint power is usually associated with lower sprint times.

In this study, normalized peak sprint power will be calculated by taking the peaks sprint power of each subject and dividing that by their mass. This will yield a value with the units of watts/kilogram. When this was done with this study's subjects, an average normalized peak sprint power of 15.54 watts/kilogram was calculated and a standard deviation of plus or minus 3.14 watts per kilogram. The normalized peak sprint power was 20.97 watts per kilogram and the minimum was 7.79 watts per kilogram.

Table 5: Normalized Peak Sprint Powers

	Normalized Peak Sprint Power (Watts/Kilogram)
Average	15.5
Standard Deviation	3.1
Maximum	21.0
Minimum	7.8

Comparison of Results to Other Studies

The study done by Stone which looks at the importance of isometric maximum strength and peak rate of force development in sprint cycling also measured vertical jump height and peak power. Unlike this study, Stone’s study was taking trained male cyclists. These cyclists also ranged in skill and ability level from local cyclists to cyclists that were competing at world level competitions. In one part of his study the subjects he tested averaged a vertical jump height of 37.3 centimeters plus or minus 7.6 centimeters. They also had a peak power of 1386 watts plus or minus 354 watts. These values in Stone’s study are very similar to the vertical jump heights and the sprint powers that were done by the subjects in this study. The data here is presented in *Table 6* This validation further solidifies that the values collected in this study are widely applicable to a range of cyclists of varying skill levels. In addition to the means, the standard deviations are also very close so the variance of the testing results also seems to show that the results that Stone found and that this study found are reproducible.

Table 6: Comparison of this study's results against Sone's results

Study	Average	Standard Deviation
Stone (Vertical Jump Height) (cm)	37.3	7.6
Mellen (Vertical Jump Height) (cm)	37.4	7.5
Stone (Peak Sprint Power) (watt)	1386	354
Mellen (Peak Sprint Power) (watt)	1157	280

Statistical Analysis- Checking for Normal Distribution

After all the data had been collected, the first step in the statistical analysis was to look to see if each of the data sets were normally distributed. This was done by looking at the P-value of each of the sets of data. A P-value greater than 0.05 denoted that the values did not have statistical significance and were normally distributed.

The results of this analysis indicated that all variables that were tested were normally distributed except for age. This was largely due to the fact that a there was a large number of younger subjects that were tested and a fair number of older subjects without many subjects being in the middle ages. Not having this middle number of subjects caused the ages to be skewed to the younger side and not allow them to be normally distributed.

Statistical Analysis- Correlation Among Variables

The next step in the statistical analysis involved looking at the correlation among different variables. This was done to see which variables expressed multicollinearity. This would help when including the different parameters into the model. *Table 6* shows the results of this correlation test. A P-value of less than 0.05 denotes statistical significance.

Table 7 shows that the only variables that are statistically correlated among one another are vertical jump height and normalized peak sprint power (NPSP), thigh circumference and mass, and height and mass. The correlation of height and mass makes sense because typically the taller someone is, the greater their mass. Also, the higher someone’s mass, typically the larger their thighs will be. The main takeaway from this is that the vertical jump height and normalized peak sprint power are statistically correlated to one another. *Figure 5* shows these two variables plotted against each other with a trendline added which shows their positive association.

Table 7: Correlation among predictor variables in the simple model

	NPSP (W/kg)	Mass (kg)	Height (m)	Thigh Circum-ference (cm)
Mass (kg)	-0.166 0.373			
Height (m)	0.124 0.505	0.510 0.003*		
Thigh Circum-ference (cm)	-0.073 0.698	0.691 0.000*	-0.033 0.858	
VJ Height (cm)	0.673 0.000*	0.064 0.730	0.341 0.061	-0.059 0.751

Cell Contents:
Pearson Product Moment Correlation Coefficient (*r*)
P-Value
* denotes statistical significance

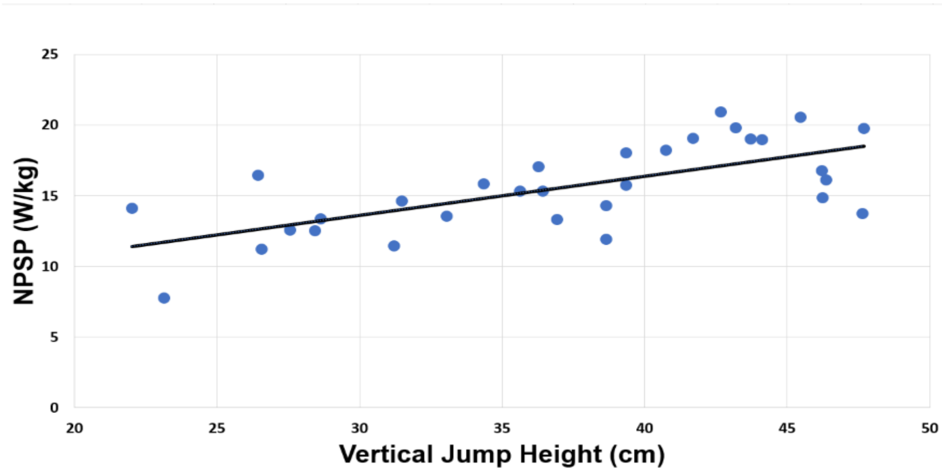

Figure 5: Plot of Vertical Jump Height against NPSP

Statistical Analysis- Regression Equation (Simple Model)

In the next part of the statistical analysis, regression equations were calculated. Several regression equations were calculated and compared among one another to determine which multiple variable regression best summarized the data. The variables that went into the stepwise regression were mass, height, thigh circumference, and vertical jump height for the simple model. These variables were used to predict normalized peak sprint power. The regression equation that was calculated is shown below in *Figure 6*.

Only the variables of mass and vertical jump height are calculated into the regression equation. The coefficients show that mass is negatively associated with normalized peak sprint power. This means that the less mass a person has for a given vertical jump height, the higher their normalized peak sprint power will be. The regression equation also shows that the higher the vertical jump height is, the higher the normalized peak sprint power will be. The R-squared for this regression equation accounts for 46.1% of the population that was tested.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	147.39	73.696	14.42	0.000
Mass (kg)	1	17.02	17.018	3.33	0.078
VJ Height (cm)	1	137.38	137.378	26.88	0.000
Error	29	148.21	5.111		
Total	31	295.60			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2.26071	49.86%	46.40%	37.42%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	9.50	3.06	3.11	0.004	
Mass (kg)	-0.0592	0.0324	-1.82	0.078	1.01
VJ Height (cm)	0.2819	0.0544	5.18	0.000	1.01

Regression Equation

Normalized PSP (watt/kg) = 9.50 - 0.0592 Mass (kg) + 0.2819 VJ Height (cm)

Figure 6: Multiple regression model for normalized peak sprint power (Simple Model)

Statistical Analysis- Regression Equation (Technological Model)

The same procedure for producing a multiple regression was followed to create the technological model. What separates the technological model from the simple model is inclusion of all of the variables that the PUSH Band recorded. This includes: vertical jump height (cm), average force (N), peak force (N), average power (watt), peak power (watt), average velocity (m/s), peak velocity (m/s), average acceleration (m/s/s), peak acceleration (m/s/s), total work (J), rep duration (s), rep duration in the concentric phase (s), and rep duration in the eccentric phase (s).

The multiple regression equation that was calculated is shown in *Figure 7*. This model also includes vertical jump height as a positive predictor of normalized peak sprint power. Instead of mass however it includes average velocity from the vertical jump. This is also positively associated with normalized peak sprint power. The R-squared for this regression equation accounts for 49.24% of the population that was tested.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	155.22	77.612	16.03	0.000
VJ Height (cm)	1	12.60	12.603	2.60	0.117
Average Velocity(m/s)	1	24.85	24.851	5.13	0.031
Error	29	140.38	4.841		
Total	31	295.60			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2.20016	52.51%	49.24%	40.48%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF

Constant	-0.02	3.10	-0.01	0.995	
VJ Height (cm)	0.1320	0.0818	1.61	0.117	2.41
Average Velocity(m/s)	7.95	3.51	2.27	0.031	2.41

Regression Equation

Normalized PSP (watt/kg) = -0.02 + 0.1320 VJ Height (cm) + 7.95 Average Velocity(m/s)

Figure 7: Multiple regression model for normalized peak sprint power (Technological Model)

Chapter 4

Conclusions and Future Directions

Outcomes of the Study Discussed

The main outcome of this study linking vertical jump height to higher normalized peak sprint power validates the study done by Loturco (10). In his study, he linked a higher vertical jump height to faster running sprint times. As discussed previously, normalized peak sprint power has been shown to be able to predict faster sprint times. Therefore, if a higher vertical jump is associated with higher normalized peak sprint power, it is also likely associated with faster sprint times.

The technological model proposed indicates that vertical jump height and average velocity are both positively associated with normalized peak sprint power. This conclusion makes sense since the higher an individual is able to jump, the more force they will be able to put out over a fixed distance over a shorter time. This translates very well to power on the bike. The height of the vertical jump also inherently takes into account the mass of the individual. Since normalized peak sprint power is calculated using mass, it is logical that the less massive a person the higher their normalized peak sprint power would be. This would also help them to jump higher because they do not have to overcome as much force caused by gravity. The study's findings also support the work done in the areas of track and field sprinting which predict that a higher vertical jump height will be indicative of a faster run time (10).

Average velocity of the vertical jump is factored into the model because this is representative of the rate of force development of the subject. The higher the average velocity means there is a greater rate of force development so therefore the individual is moving at a faster velocity over the entire takeoff portion of the vertical jump. This supports the findings of other research that emphasize the importance of rate of force development in sprint cycling (11).

The results of this study show that there is statistical evidence to prove that a higher vertical jump height will be associated with a higher normalized peak sprint power. This means that training regimens designed to increase vertical jump height also have a good likelihood to increase normalized peak sprint power on the bike. The exercises typically target strong and powerful movements which could complement a sprint cyclists training regimen.

One of the biggest outcomes of this study is the ability to assess an athlete's normalized peak sprint power through inexpensive means like measuring a vertical jump height utilizing the simple model. This type of assessment could be used by coaches as an inexpensive and quick means of assessing where an athlete is at or how they are responding to training. In some training schemes this could be used to test the readiness of an athlete for the day of training. If they do not hit a certain height in the vertical jump the training could be adjusted to lighten the training load. This method could also be used in a talent identification setting where it would be impractical for a large group of individuals to all perform power tests using a power measurement device. The people that are being evaluated could be massed and then perform a simple vertical jump test. This could then be put into the Simple Model to calculate an estimated normalized peak sprint power. Those that show potential could then move onto further, more in depth testing.

Further Research

One area that this study did not look at was looking for associations between a maximal strength test and normalized peak sprint power. The study done by Stone shows that this was an effective predictor of normalized peak sprint power. If this information was added into the multiple regression model it may have been able to represent more of the population of subjects which would ultimately give a better predictor of normalized peak sprint power.

Another area that could be looked at further, is narrowing the inclusion criteria of subjects. A separate study for men and women may be helpful in predicting more accurately normalized peak sprint power. Additionally, if the skill level of the cyclists was limited, it may be more applicable to that specific age and ability range than this study. For example, if this were to be used in a talent identification setting it may be beneficial to look at how inexperienced athletes performed in the simple tests and then how they would perform after a set amount of training.

Additionally, other anthropometric measures could be investigated further. Measures like fat free mass and percent body fat may give good insight into the overall fitness of an individual. If this test was being used for talent identification this would be valuable information to be able to investigate if an induvial had potential but was not physically fit. With the current measurements this person would not show much potential because their body mass was elevated even though they may be predisposed to a sprint discipline.

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ACADEMIC VITA

Academic Vita of James Mellen
Email: jsmellen5@gmail.com

Education:

Major: Biomedical Engineering
Honors: Biomedical Engineering
Thesis Title: Assessment of demographic, anthropometric, and physical performance variables as predictors of sprint cycling power
Thesis Supervisor: Giampietro Vairo

Grants Received: Penn State Center for the Study of Sports in Society Grant Recipient (2017)

Awards:

Richard Laird Smith Memorial Scholarship (2015-2016)

Penn State Commonwealth Campus Awards (2014-2016)

The President's Freshman Award (2014-2015)

Professional Experience:

Technical Design Consultant (2014-Present)

- Test and evaluate Power Meters, Shoe Closure Systems, and Bicycle Components for various companies
- Offer design suggestions to improve product functionality and enhance marketability

Pennsylvania State University Learning Center, Center Valley (2015-2016)

- Official university tutor
- Ensure the success of 10+ tutees in their calculus, chemistry, and physics courses

Project Lead the Way (2010-2014)

- Focus on principles of engineering, biomedical engineering, and aerospace engineering

- Applied the design process and accepted engineering practices to various design projects

Emerging Health Professionals (2013-2014)

- 80+ hours shadowing in the health profession
- Proficient in skills required in the healthcare profession

Athletics:

Track Cycling (2012-Present)

- Ranked number 1 in the United States in the Elite Men's Sprint and Keirin
- Represented the United States in the Pan American Track Cycling Championships in Trinidad and Tobago
- Member of 2 Junior World Championship teams competing in Glasgow, Scotland and Seoul, South Korea
- 9X National Champion

Leadership Experience:

Student Orientation and Transition Program Leader (2016-Present)

- Ensure success of students when making their transition to University Park
- Give support and guidance to students in need
- Assist in coordination of events for 500+ students

Community Bike Works (2015-Present)

- Teaches life lessons through bicycle mechanics to inner city children
- Uses role models in a mentorship style program to teach teamwork and work ethic

Eagle Scout (2014-Present)

- Project leader and supervisor in designing and building a hiking shelter in the Lehigh County Game Preserve
- Coordinated project implementation with Minsi Trails Council, Lehigh County, United Way Teen Works.