2018

Correlation Between the Spirit Bike Maximal Power Output and Other Lower Extremity Power Output Tests

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BY

Tyler Adams, Joseph Brown, Gunnar Mendiola, Ryan Sullivan, Cody Williams

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Acknowledgements

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SECTION I:

ABSTRACT

BACKGROUND:
The assessment of a patient's lower extremity function is important for physical therapists to make clinical judgements about the subject's mobility and physical capabilities. For physical therapists to accurately assess a patient's lower extremity function, clinicians must utilize the most appropriate tests, evaluation techniques, and/or tools. It is not clear that single leg hop tests will provide the most accurate assessment of lower extremity function for patients with hip, knee, ankle, and or foot biomechanical dysfunctions, as in some severe cases, these tests may even be contraindicated.
PURPOSE:
The purpose of this study is to analyze the correlation of lower extremity power between maximal output on the Spirit MU 100 upright lower body ergometer and specific single-leg hop tests.
STUDY DESIGN:
Quasi-experimental
SETTING:
The study was conducted in Armstrong State University's Biodynamics and Human Performance Center.
POPULATION:
A total of 43 participants were recruited to participate in this study.
METHODS:
Participants were involved in 2 testing sessions, each completed within 10 days. Randomization was used to determine which testing protocol each subject would perform and for determining the order of the tests within each protocol.
RESULTS:
40 subjects: 19 males and 21 females completed this study. All Pearson's R^2 correlation values were between 0.44 and 0.49, indicating a moderate relationship.
DISCUSSION:
We hypothesized that the study results would yield a strong positive correlation. Nevertheless, we believe that the results still provide significant implications to clinical practice, and with additional research may produce a higher positive correlation.
CLINICAL APPLICATION:
This study analyzed the correlation of lower extremity power between the Spirit MU 100 upright lower body ergometer and specific single-leg hop tests. With a moderate positive level of correlation, we suggest that for certain patients where the single-leg hop tests are contraindicated that the Spirit MU 100 upright lower body ergometer may be used to assess their lower extremity function.

INTRODUCTION

Physical therapists are relied upon to assess and make clinical decisions based on a patient's lower extremity (LE) function. According to Logerstedt et al.[11] and Grindem et al.[6], the gold standard for determining lower extremity power, along with return to activity, is the single leg hop (SLH) test. Single leg hop tests are analyzed to compare the power and level of function between each lower extremity. The Limb Symmetry index (LSI) is a formula that can be utilized to provide objective data that determines how functionally similar the injured LE is to the non-affected side. This method of assessment was implemented by Noyes et al.[12] (American Journal of Sports Medicine) for subjects with ACL injuries, which is promoted by the International Knee Decision Committee (IKDC). The SLH tests can be used in conjunction with the LSI. However, the SLH test may not be suitable for individuals with certain biomechanical dysfunctions. Examples of patient populations that might be inappropriate for such a test include the elderly and those with decreased neuromuscular control, such as Guillain–Barré syndrome and post-polio syndrome.

Currently, there is limited research on alternative ways to assess LE function in place of the gold standard tests for patients who may be unable to safely perform a SLH. However, some literature suggests that an upright lower body cycle ergometer can be used to efficiently assess LE power.[1, 14] Cycle ergometry coupled with allometric scaling could be a safe alternative to the SLH test when determining return to activity.[13] Allometric scaling is a general logarithmic equation that can be utilized to estimate objective measures for physical performance based upon proportional body size. An example of the utilization of allometric scaling would be to compare the distance that an individual could jump relative to their height. The significance of our study is that it has the potential to suggest an alternative assessment to SLH tests to encompass a more debilitated patient population. The purpose of our study was to assess the relationship between the peak power output on the Spirit MU100 upright lower body ergometer to the SLH for return to activity. Our group hypothesized that we would obtain a strong positive correlation between performance on the hop tests and peak power from the Spirit Bike.

SECTION II:

METHODS

DESIGN

The research design implemented a quasi-experimental method. Randomization of subjects was performed with a random number generator from the website https://www.random.org/sequences. Randomization was used to determine which testing protocol each subject would perform first, and for determining the order of the hopping/jumping procedure. Participants were involved in 2 testing sessions, each completed within 10 days. Subjects read and signed an informed consent form and a medical questionnaire at the beginning of their first testing session. The subjects then performed a 5 minute warm-up on the Spirit MR100 cycle on level 2 resistance, at a self-selected cadence. Next, a 2 minute rest break was taken prior to testing.

SUBJECTS

Participants included physically active males and females, as defined by the American College of Sports Medicine (ACSM). The participants recruited were Armstrong State University students, staff, faculty, and persons from the surrounding community. Recruitment consisted of posting flyers on campus property and verbally through personal interaction. Inclusion criteria consisted of subjects between 18-60 years of age, who have not experienced lower extremity pain within the last 14 days, and have no history of lumbar spinal or lower extremity fracture or surgery. Exclusion criteria consisted of lower extremity pain greater than 0/10 on a Numeric Pain Rating Scale (NPRS) during the past 14 days, previous lumbar spine or lower extremity fracture or surgeries, any major medical condition, pregnancy, and/or cognitive impairments. A Pearson R squared power analysis indicated 40 subjects were required. Forty-

three participants were initially selected for testing, 40 of which completed the entire testing protocol.

INSTRUMENTATION:

Testing was performed at Armstrong State University's Biodynamics and Human Performance Center. Each testing session lasted approximately thirty minutes and consisted of either the stationary bicycle protocol or the jump testing protocol. The Spirit MU 100 upright lower body ergometer was used for maximal sprint testing for power, while the Spirit MR 100 recumbent lower body ergometer was used for warm-up protocols. A Vertec vertical jump apparatus was used for the vertical jump protocol, while the SLH test protocols were performed on an open, carpeted area that was measured and taped for distance readings. All data collection was recorded in Microsoft Excel. A Borg rating of perceived exertion (RPE) scale was posted for all participants to view and was used as a reference during the testing procedure; the scale is a subjective measure of effort given during a task or activity.

TEST FORMAT

Prior to testing, each participant was read a standardized script that directed the participant through the test procedures. For the cycle protocol, seat height of the testing cycle ergometer was adjusted to the level of the participant's greater trochanter of the femur prior to testing. All participants were instructed to maintain proper seated position during all bouts of testing. Participants then performed three, 5 second warm-up sprints at increasing resistance levels. The resistance levels were preset into the lower body ergometer with each level applying a peak resistance. Resistance levels of the cycle were standardized to levels 10 (320W), 15 (483W) , and 20 (628W) for males and levels 4 (125W), 7 (219W), and 10 (320W) for females. Subjects were instructed to cycle at 25% of self-selected maximal effort for the first warm-up

sprint, 50% for the second sprint, and 75% for the last warm-up sprint. A rest period of 30 seconds was allotted between warm-up sprints and 1 minute between the 3 maximum trials. The resistance levels of the maximum trial sprints were chosen based on the RPE reported after the third warm-up sprint. A RPE less than 16 indicated an increase of 5 resistance levels. An RPE between 17-18 indicated an increase of 3 resistance levels. A RPE between 19-20 indicated an increase of 2 levels. These levels were chosen in order to reach a true maximum power output in the fewest number of trials. The maximum effort sprints were performed for a maximum of 10 seconds each. Resistance levels were increased if a participant attained the maximum power output for that level; each resistance level had a maximum attainable power, so achieving this number indicated that an individual met or exceeded the limit of that particular level and a true "maximum" was not obtained. Participants continued performing maximum effort sprints until they could no longer reach the maximum power for a given resistance level. The total number of trials, final resistance level, and final power output in watts was recorded for each subject.

The SLH test was performed using the same warm-up progression as the cycle test. Participants performed 3 single leg hops: one at 25%, one at 50%, and one at 75% of self-selected maximal effort. Participants were provided with a 30 second break between warm-up testing and maximum effort testing. Three maximal effort hops were performed after the warm-up progression. Participants were instructed to place their self-determined dominant foot at the base of the measuring tape with toes at the "zero" mark. Participants were then directed to balance on their dominant leg by raising the non-dominant foot off of the floor. Participants were then told to perform a maximal effort single leg hop, land with the dominant foot, and maintain balance. Participants were instructed to avoid placing their non-dominant leg on the ground until balance was maintained for at least 2 seconds. If a participant was not able to maintain balance

for 2 seconds, or landed with both feet at the same time, the attempt was not recorded. Once 3 recordable maximal effort hops were completed, the participant switched to the non-dominant leg and performed the same procedure as the dominant leg. The farthest distance of the 3 maximal attempts was recorded for each leg.

The crossover hop test was performed in the same manner as the SLH test. The only difference was that the participant would land on the opposite leg of the initial leg that was placed on the ground at the start of the test. All warm-up efforts and maximal efforts were performed in the same progression. The farthest distance of the 3 maximal attempts was recorded for each leg.

The Sargent's vertical jump test was also performed with 3 warm-up jumps at 25%, 50%, and 75% of self-selected maximal effort, followed by 3 maximal effort jumps. Before testing, participants' maximal standing vertical reach was recorded by standing against a measuring wall and reaching up with his or her dominant hand. This measurement was used in conjunction with the data recorded on the Vertec jump apparatus to determine the subject's vertical jump height. The subjects were allotted a 30 second rest break between progressive warm-ups and maximal jump testing. Participants were instructed to place both feet in the starting position below the Vertec jump apparatus, jump using both legs, use their dominant hand to hit the vanes, and land safely on both feet. Participants were allowed to swing their arms upon jumping, but were not allowed to take a step prior to jumping. Maximal vertical jump was recorded by subtracting the height of the highest vane from the participant's standing reach height.

All of the hopping/jumping tests were performed in one session with 2 minute rest breaks between each test. The order of the tests was randomly selected for each subject. The cycle protocol was performed in a separate testing session.

RESULTS

STATISTICAL ANALYSIS

Each jump test was compared against the value for maximal power output on the Spirit cycle ergometer. Correlation was assessed using a Pearson's R^2 for each with Microsoft Excel 2010 software. All calculated values were between 0.44 and 0.49, indicating a moderate level of correlation. Individual correlational analysis of the SLH and crossover tests showed that the left leg had a marginally higher R^2 compared to the right leg. Figures 1 through 5 demonstrate the correlational results comparing each hop test to the maximum power output readings obtained from the Spirit cycle ergometer as well as the corresponding R^2 values and a best fit prediction equation. Ranked from highest to lowest the tests with strongest correlations to the Spirit cycle ergometer are: left single leg hop test, left crossover hop test, right crossover hop test, right single leg hop test, and Sargent vertical jump test.

RESULTS:

Initially, 43 subjects were recruited to participate in this study. Three subjects did not complete follow-up testing and were subsequently removed from the data pool. The final sample of 40 subjects was very evenly distributed among gender with 19 males and 21 females. The ages of subjects ranged from 18 to 30 years old, with the average age being 23.1 years old. Leg dominance was heavily skewed, with 36 subjects being right leg dominant and only 4 being left leg dominant.

DISCUSSION

The purpose of our study was to assess the relationship between the peak power output on the Spirit MU100 upright lower body ergometer to the SLH for return to activity. After analyzing the data, a moderate level of positive correlation was found between the Spirit MU 100 lower body ergometer and the specified hopping/jumping tests. Prior to collecting data, we hypothesized that the results would indicate a strong relationship. Due to these findings, we reject our hypothesis. Nevertheless, the obtained correlation outcomes should not be discounted. A perfect correlation is not possible due to the biomechanical differences between the hopping/jumping tests and the pedaling of the cycle ergometer. Additionally, the resulting moderate level of significance may still suggest an alternative method of assessing lower extremity power and function, especially in biomechanically compromised patients.

LIMITATIONS

All research studies have potential limitations, which can restrict the accuracy and precision of the research results. Identified limitations and extraneous variables within this study include the following: Novelty of tasks, fatigue, and internal factors impacting participant's performance.

Novelty of tasks can be a major restriction component to research, especially when performed at maximum effort. Unlike some foreign countries, Americans typically do not ride bicycles on a daily basis. Additionally, most individuals are not required to perform hop tests or a vertical jump on a frequent basis. Due to a lack of experience, participants may have lacked sufficient motor coordination to efficiently control his or her motions at peak capacity. To minimize this limitation, warm-up protocols and a series of maximum trials were performed in order to capture the participant's true maximum effort.

Fatigue is another potential limiting factor for this study. Due to the lack of defined parameters for maximum power testing on the Spirit cycle ergometer, our group collated procedures from the Balke protocol, Bruce protocol, and Wingate protocols in order to extrapolate methods that apply more specifically to our study design. The goal of the study protocol was to obtain the participant's true maximal power output within the 3 trials. However, a few participants did require an additional maximum trial to reach their true maximum. Therefore, fatigue could have affected these participants and potentially decreased their true maximum power output.

The majority of our study population consisted of college aged students. These students can experience a variant number of internal conflicts on a weekly basis, ranging from a lack of sleep, stressing over an exam, or financial burdens. These internal conflicts could limit a participant's performance. Conversely, college aged students are generally more active compared to the population as a whole which could feasibly skew results. Lastly, three participants were lost to follow-up testing and were not able to be reached for study completion. These lost participants may have detracted from the power of the sample, but the power analysis of forty participants was still obtained by the following number of participants.

CONCLUSION

In conclusion, the Spirit MU 100 could potentially be the new “Gold Standard” for return to activity for biomechanically compromised patients. This study aimed to establish the cycle ergometer’s efficacy and overall clinical application, as it relates to maximal power output. However, more clinical research needs to be done in order to further assess the true potential of the Spirit MU 100 efficacy and applicability.

CLINICAL APPLICATION

Clinical application is a major driving component to many research studies. This research warrants potential for clinical application in more than one clinical scenario. As noted in the results section, the maximum power output value on the Spirit cycle ergometer can be input into a prediction equation (noted on Figures 1-5) and yield an estimated performance on the selected hop test. The predicted performance distance on the hop test can then be applied to allometric scaling and/or limb symmetry index. This is vital for biomechanically compromised patients, because we can now implement the research behind allometric scaling and limb symmetry index without having to perform a hop test.

SECTION III:

Literature Review

The validity of power output recorded during exercise performance tests using a Kingcycle air-braked cycle ergometer when compared with an SRM powermeter

J. Balmer, R. C. R. Davison, D. A. Coleman, S. R. Bird 1999

- Cycle ergometry, when compared to a power-measuring crankset, showed that the bike overestimated power. Differences were approximately 10% higher. There is variability among different bike models, so there needs to be more consistency in measurement.

Force-velocity relationship and maximal power on a cycle ergometer - Correlation with the height of a vertical jump

H. Vandewalle, G. Peres, J. Heller, J. Panel, and H. Monod 1987

- Power output and jump height had a highly linear relationship in well-trained subjects. It was not established that prediction was possible between jump height and power output, but there was a high degree of agreement.

Maximum leg force and power output during short-term dynamic exercise

Anthony J Sargeant, E Hoinville, A Young 1981

- Forces for each leg during cycle power testing was calculated, differences between which leg was working were obtained. Only one leg is working at a time, compared to simultaneous muscle work in jump testing. Peak angle for power was about 90 degrees past the apex of revolution.

Cadence, power, and muscle activation in cycle ergometry

Brian R. Macintosh, Richard R. Neptune, and John F. Horton 1999

- Maximal power output requires maximal subjective effort, but there is not a certain cadence that achieves maximal power. Submaximal power output can be achieved through a variety of different cadences based on necessary muscle activation, with an optimal cadence possible. Electromyographical activity of muscles increases as cadence increases, meaning the minimal activation increases in kind. Roughly 100 rpm is hypothesized to be an ideal efficient cadence for submaximal power.

Reliability of power in physical performance tests

Will G. Hopkins, Elske J. Schabort, and John A. Hawley 2001

- The tests with the highest reliability were peak power in an incremental test and mean power in a constant power test. While these had the highest agreement, the most reliable test may not necessarily be the best for tracking change. Field tests also showed marginally higher reliability than ergometry tests.

Measurement of work and power output using friction-loaded cycle ergometers

Lakomy, HKA 1986

- The flywheel on an ergometer requires overcoming initial friction upon the initiation of movement. Power calculations do not generally factor in this increased load and are subsequently affected in accuracy. Instantaneous power was greatly underestimated, but total work done was unaffected by correction

Reliability and validity of the Velotron racermate cycle ergometer to measure anaerobic power

Astorino, T. A., & Cottrell, T

- This study assessed the reliability and validity of the Velotron Racermate cycle ergometer to assess anaerobic power. Compare Velotron Racermate to "gold standard" Monark Ergometer. When an electrically-braked cycle ergometer is used to administer the Wingate Test, data may differ from values obtained using a mechanically-braked device. Thus the data can not be used interchangeably between different device setups in the clinic

Comparison between treadmill and bicycle ergometer exercise tests in mild-to-moderate hypertensive Nigerians.

Abiodun

- Maximal exertion testing on a treadmill causes higher cardiovascular responses in patients than bike testing, thus giving you a better diagnostic tool. However, this might not be generalizable to our population.

A comparison of one-legged and two-legged countermovement jumps

Van Soest, AJ et al.

- Study comparing biomechanical differences between unilateral and bilateral jumping motions. Measures were taken for electromyography activity of lower extremity musculature, joint angles and angular motion, and ground reaction forces. Authors found that overall single leg jump height was at least 50% of double leg jump height.

The Present status of physical fitness in the Air Force

Balke, B., & Ware, R. W. (1959)

- The original study detailing a protocol for assessing work capacity via progressive exercise testing. Work capacity is measured through oxygen uptake during exercise. The testing procedure was useful for developing our testing script and methods.

Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise

Garber, Carol Ewing Ph.D et al.

- American College of Sports Medicine Position Stand for exercise prescription in healthy adults. This was used to define inclusion criteria of subjects.

The wingate anaerobic test: An update on methodology, reliability and validity

Oded Bar-Or (1987)

- Update on the original Wingate protocol developed in 1974. The author includes all relevant testing procedures but applies them to recreationally active individuals to assess sport to sport differences. The article was useful in helping to develop our testing procedures.

Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease

Bruce, R., Kusumi, F., & Hosmer, D. (1973).

- Original study detailing a protocol for progressive exercise testing for maximal and sub-maximal exercise performance. The study was geared towards cardiovascular pathologies and identifying functional impairments within the cardiovascular system. The study was useful in developing our methods and testing procedures.

Peak power during repeated wingate trials: implications for testing.
Kohler, R. M., Rundell, K. W., Evans, T. M., & Levine, A. M

- The study compared multiple warm-up protocols prior to performing Wingate trials to determine optimal peak power testing procedures. The authors concluded a general self-selected warm up protocol was most appropriate, and testers should allow for a familiarization trial prior to formal testing. Testers should also ensure full recovery between trials.

Single-legged hop tests as predictors of self-reported knee function after anterior cruciate ligament reconstruction: the Delaware-Oslo ACL cohort study.
Logerstedt, D., Grindem, H., Lynch, A., Eitzen, I., Engebretsen, L., Risberg, M. A., Snyder-Mackler, L.

- The study assessed single leg hop test performance in subjects preoperatively, 6 months, and 1 year after Anterior Cruciate Ligament construction. The authors concluded single leg hop tests performance 6 months after Anterior Cruciate Ligament reconstruction were good predictors of self-reported knee function at 1 year. This study was used to develop the testing procedure for the single leg hop and crossover hop tests.

Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture.
Frank R. Noyes, Sue D. Barber and Robert E. Mangine

- This study assessed the sensitivity and specificity of four different types of one-legged hop tests (single hop, timed hop, triple hop, and cross-over hop). The goal was to determine the sensitivity of each in detecting abnormal lower limb symmetry in ACL deficient patients and to determine the two most sensitive tests that could be in determining results of treatment programs and functional limitations in ACL deficient knees. The results indicated that these hop tests had a low sensitivity rate. However, the high specificity and low false-positive rates allow the tests to be used to confirm suspected defects in lower limb function.

Optimal loads for a 30s maximal power cycle ergometer test using a stationary start
Nicole T. Vargas, Robert A. Robergs, Dawn M. Klopp

- This study was performed to determine, for a stationary start modification to the Wingate Anaerobic Test if the traditional 85 g/kg body weight load, or an individualized optimal load, is more suitable for obtaining peak and mean power outputs for a stationary start. It is not necessary to use an optimal load setting to acquire maximal power output for a 30-s cycle test using a stationary start. Instead, the traditional 85 g/kg BW loading is suitable for both males and females.

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Section IV: Appendices

Appendix A: IRB proposal and Approval Letter

Armstrong
STATE UNIVERSITY

Use this form to request review and approval of a new project before it is initiated. All persons listed as researchers (including students, faculty, and staff), supervising faculty, and signatory unit supervisors (e.g., heads and deans) shall attach certificates of completion of the NIH web-based training course "Protecting Human Research Participants". Certificates are valid for three years. Go to http://phrp.nihtraining.com/users/login.php for the NIH training modules.

Primary Researcher Responsible for this IRB Application: Gunnar Mendiola

Mailing Address of Researcher: Street: 11910 Abercorn St.
City/State/ZIP: Savannah, GA 31419

Academic Unit of Researcher: Rehabilitation Sciences

Telephone numbers of Researcher: Armstrong: 912-344-3341 Home: 912-344-6394

E-mail Address of Researcher: spiritbike.study@gmail.com

Status of Primary Researcher: ☐Faculty ☒ Student ☐ Staff Other

If the researcher is a student, name of supervising faculty: Dr. Frank Glenn, Dr. George Davies

Signature of supervising faculty: _____

Names and Status of Additional Researchers: students: J. Tyler Adams, Joseph Brown, Ryan Sullivan, Cody Williams

Project Title: How does the Spirit MU100 upright cycle ergometer measurement of lower extremity power compare to the lower extremity gold standard for power?

Name of financial sponsor (or prospective sponsor) of the project, if any: None

Proposed beginning date: 8/01/2016 Proposed completion date: 5/15/2018 (Final report is due)

_____ _____ _____ _____ Signature of Head of Unit Date Signature of Dean of College Date

The signatures above indicate that the dean and unit head have read the research proposal and are aware of its contents. The signatures indicate neither approval nor disapproval of the research project. They indicate only that the proposal has been read by the supervisors and is being sent to the University's Institutional Review Board.

I certify that the statements made in this request are accurate and complete, and if I receive IRB approval for this project, I agree to inform the IRB in writing of any emergent problems or proposed procedural changes. I agree not to proceed with the project until the problems have been resolved or the IRB has reviewed and approved the changes. It is the explicit responsibility of the researchers and supervising faculty/staff to ensure the well-being of human

participants. At the conclusion of the project I will submit a report. A report must be submitted no later than 12 months after project initiation.

Signature of Primary Investigator Date

Applicants should insert all text into the appropriate text boxes. The text boxes expand to allow unlimited entry.

I. Briefly state rationale of study and hypothesis:

Lower extremity power is a functional outcome for rehabilitation patients and can be used as a means of discharge purposes and/or assessing patient progress. Lower extremity muscle power is also correlated with the risk for falls. The current lower extremity power tests are: Single-leg hop (Gold Standard), double-leg jump, and double-leg counterforce Sargent's vertical jump. However, those tests may be contraindicated for people with certain conditions. The purpose of this study is to determine the strength of the correlation between lower extremity power tested via the Spirit MU100 upright cycle ergometer and the single-leg hop, the double-leg jump, and the double-leg counterforce Sargent's vertical jump tests. We hypothesize that the strength of the correlation will determine the Spirit MU100 upright cycle ergometer as a viable alternative for lower extremity power testing for those for whom the comparative tests are contraindicated.

II. The Human Subjects Involved in this Research:

1. Who are the subjects?

Physically active males and females as defined by the American College of Sports Medicine (ACSM) who include voluntarily recruited ASU students, staff, faculty, and persons from the surrounding community who: Are 18-60 years of age, have not experienced lower extremity pain within the last 14 days, and have no history of lumbar spinal or lower extremity fracture or surgery.

2. How many subjects are involved?

mum of 45 subjects; the same for each test (per power analysis).

3. How will you recruit the subjects? Describe any written or verbal solicitations.

Flyers will be posted around campus and the surrounding community and by verbal communication of the need for volunteers to faculty and staff. Please see the attached flyer.

4. If you use a participant screening instrument, describe the instrument and the exclusion or inclusion criteria as they explicitly relate to the instrument. Submit a copy of the instrument with this application.

Inclusion criteria for subjects are: 18-60 years of age, physically active as defined by the ACSM, have not experienced lower extremity pain in the last 14 days and are fluent in written and spoken English. Exclusion criteria include: Experience lower extremity pain greater than 0/10 on a Numeric Pain Rating Scale (NPRS) during the past 14 days, previous lumbar spine or lower extremity fracture or surgeries, any major medical condition, pregnancy, and/or cognitive deficits. Please see the attached: Numeric Pain Rating Scale, The Biodynamics and Human Perfomance Center at Armstrong Atlantic State University Medical History for Research form (dated 4/6/2015).

5. How long will each subject be involved in the project? (Number of occasions and duration)

Each subject will be involved in 2 testing sessions of approximately 1-1.25 hours each. Both sessions will be completed within 10 calendar days.

A. YES NO N/A (Please mark the appropriate column and provide details as necessary)

1. ☒ Are you advertising or posting a notice for volunteers over media?

If yes, attach a copy of the advertisement or notice.

2. ☐ Are you compensating your subjects with money, course credit, extra credit, or other incentives? If yes, indicate how much and describe how you will compensate subjects who withdraw from the project before it ends.

3. ☒ Are your subjects Armstrong State University students?

4. ☐ ☒ Are your subjects students at an institution other than Armstrong State University? If yes, name the institution(s) at which they are enrolled.

B. Do your subjects include any of the following:

YES NO N/A (Please mark the appropriate column)

1. ☐ ☒ ☐ Infants and children younger than 7 years?

2. ☐ ☒ ☐ Institutionalized mentally impaired people?

3. ☒ ☐ ☐ Students enrolled in your own classes?

4. ☐ ☒ ☐ Prisoners?

5. ☐ ☒ ☐ Other special populations? If yes, specify.

III. The Research Procedures:

Please check the appropriate box if your research procedure involves:

☐ Ingesting, injecting, or absorbing any substances into the body
☐ High expenditures of physical effort that could lead to physical injury
☐ Inserting any objects into bodies through orifices or otherwise

Checking one of the above boxes indicates a full review may be necessary

Describe in concise terms and with limited jargon your complete research protocol. Describe in chronological order what participants are expected to do. Include copies of questionnaires, surveys, and/or interview questions used and specify tasks given as attachments to this document.

Research Protocol:

Subjects will fill out an informed consent form approved by the ASU IRB committee. Subjects will complete a NPRS form. At the completion of this scale, if a subject has experienced pain greater than 0/10, they are excluded from this study. They will then fill out a medical questionnaire that screens for various medical conditions and collect information concerning demographics, activity level, height, and weight. The medical questionnaire will identify information concerning pre-existing lumbar spine or lower extremity injuries that would prevent participation in this study. If subjects have any previous lumbar spine or lower extremity surgeries, they will be excluded from this study. The data collection period consists of two sessions that last approximately one hour to one hour and a quarter (60-75 minutes). The hop and jump tests will be performed during one session and the cycle test will be performed during another session; the order of the sessions will be randomized as well as the order of the hop and jump tests.

The single-leg hop test: The subject will receive a demonstration on how to perform the assigned test. The subject will perform a 5-minute total body warm-up using either a bike, elliptical, or treadmill. The subject will be directed to perform stretches of the quadriceps, hamstrings, and ankle dorsiflexors. The subject will then perform 4 gradient warm-up hops: 25%, 50%, 75%, and 100% of maximal effort. The subject will then perform 12 maximal effort single-leg hops taking off and landing on the same leg and taking off and landing on the opposite leg. A rest period of 2 minutes will occur between each set of hops. The subject will be monitored by the researchers throughout the warm-up and testing period to ensure safety.

Double-Leg Jump: The subject will receive a demonstration on how to perform the assigned test. The subject will begin with toes behind the assigned line, perform a maximal distance jump, and a measurement will be taken from the initial starting position to the foot placement position when landing. A measurement will be taken from the front of the foot in take-off to the

front of the foot upon landing. The subject will perform 4 gradient warm-up hops: 25%, 50%, 75%, and 100% of maximal effort. A 20 second rest between trials will be given to subject. The subject will then perform 3 double-leg jumps at 100% max effort (20 second break between trials) and the highest score of the 3 trials will be recorded. The subject will be monitored by the researchers throughout the warm-up and testing period to ensure safety.

Sargent's Vertical Jump: The subject will receive a demonstration on how to perform the assigned test. Testing will be performed on the vertex, in order to maintain accuracy. The distance of the subject's reach will initially be measured by the subject reaching up with the preferred hand while keeping both feet directly under the vertex. Subject will perform 4 gradient warm-up jumps at 25%, 50%, 75%, and 100% of maximal effort. A 20 second rest between trials will be given to subject. The subject will then perform 3 vertical jumps at 100% max effort (20 second break between trials) and the highest score of the 3 trials will be recorded. The subject will be monitored by the researchers throughout the warm-up and testing period to ensure safety.

The Spirit MU100 cycle ergometer test: The subject will perform a 5-minute warm-up on the bike (cycle) with a self-selected cadence. Subjects will be allowed to adjust the seat height and handlebar height for comfort. During the warm-up, three 5-second sprints will be performed at 2, 3, and 4 minutes. Subjects will be allowed a 3-minute rest period after the warm-up during which they will be able to continue cycling or stop and stretch. The testing procedure will follow an incremental sprint progression consisting of a 25%, 50%, 75% effort sprint for 20 seconds each and a 30-second rest period between each sprint. Three trials of 100% effort sprint for 20 seconds each will be conducted with the maximum power output recorded.

A. Specific questions about the research procedure:

YES NO N/A (Please mark the appropriate column and provide details as necessary)

1. ☐ ☒ Will you obtain information about your subjects' private behavior, economic status, sexual preferences, religious beliefs, or other matters which, if made public, might impair their self-esteem or reputation? If yes, describe how you will ensure all your data are kept secure and confidential:

2. ☒ ☐ Will any identifying information associated with the subjects be collected in the course of the study (such as names, phone numbers, IP addresses, etc.)? Describe how the identifying information will be separated from the data if anonymity is promised.

Subjects will have an ID number to separate from identying information.

3. ☐ ☒ Does your study involve deception of your subjects? If yes, give an explanation of why deception is necessary, and describe how you will debrief your subjects. Provide a copy of the debriefing statement, and the timeframe in which it will be given to participants.

4. ☒ ☐ Are you willing to allow subjects to withdraw after debriefing and remove from your data all records of their involvement? If not, why not?

4. ☐ ☒ Are there prospective subjects who might be especially vulnerable to risk due to your procedures? If yes, describe how you will screen and eliminate all vulnerable subjects from the study.

5. ☐ Will ☒ you ☐ be carrying out procedures or asking questions that might disturb your subjects emotionally or produce stress or anxiety? If yes, describe your plans for counseling and treating such subjects.

6. ☒ Are ☐ you ☐ using a questionnaire or structured interview as part of your procedure? If yes, submit a copy of the questionnaire(s) and/or interview questions.

7. . ☐ Are ☒ you ☐ using copyrighted material as part of your research?
If yes, attach the approved request for copyright permission.

8. Describe how legally effective informed consent will be obtained. Attach a copy of the consent form. If minors are to be used describe procedures used to gain consent of their parent (s), guardian (s), or legal representative (s), and gain assent of the minor.

Subjects will be given the attached Consent Form and the Department of Rehabilitation Sciences Patient Release Form. Each subject will be informed about the details of the study and the relative risks associated. Please see the attached consent and release forms.

9. Describe the final disposition of your data (notes, drafts, lists of subjects, photographic records, tapes, etc.) after you have completed your research. Describe who will be charged with keeping and disposing of the data, how long they will be kept, and how they are to be permanently made unavailable. Note: Student researchers must specify which faculty or staff member will be responsible for records after you have left the university.

All subject information will remain confidential by keeping it locked in the Biodynamics and Human Performance Center until it is ready for analysis. Upon completion of the study, the relevant data will be taken from the forms and any personal information will be destroyed.

10. Describe a medical emergency plan if the research involves any physical risk beyond the most minimal kind. The medical research plan should include, but not necessarily be limited to, emergency contact numbers of researchers, stipulating whether a landline (with phone number) is available in the research setting, emergency equipment appropriate for the risks involved, first rescuer actions to address the most likely physical risk of the protocol, second rescuer actions to address likely physical risks, and the campus police call number (912.344.3333).

Please see the attached Armstrong Biodynamics & Human Perfomance Center Emergency Action Plan.

Armstrong State University

Notice of IRB Approval

Name: Gunnar Mendiola

Co-Investigators: J. Tyler Adams, Joseph Brown, Ryan Sullivvan, Cody Williams and Faculty Advisors, Frank Glenn and George Davies

Academic Unit: College of Health Professions

Date: August 5, 2016

RE: # 1371 How Does the Spirit MU100 Upright Cycle Ergometer Measurement of Lower Extremity Power Compare to the Lower Extremity Gold Standard for Power?

The above project has been reviewed and is approved by the IRB under the provisions of Federal Regulations 45 CFR 46. This approval is based on the following conditions:

1. The materials you submitted to the IRB provide a complete and accurate account of how human subjects are involved in your project.
2. You will carry on your research strictly according to the procedures as described in the materials presented to the IRB.
3. You will report to the IRB any changes in procedures that may have a bearing on this approval and require another IRB review.
4. If any changes are made, you will submit the modified project for IRB review.
5. You will immediately report to the IRB any problem(s) that you encounter while using human subjects.

Signed 

Donna Brooks, Chair IRB
Armstrong State University

cc:

Appendix B: Participant Recruitment Flyer

Are you willing to test a brand new piece of exercise equipment?

A team of Armstrong Physical Therapy students is looking for healthy individuals age 18-60 years old to participate in a research study using a new upright exercise bike.

Participants will

- Fill out a short health questionnaire
- Attend 2 brief sessions in the Armstrong Biodynamics Lab lasting about 30 minutes each

Contact spiritbike.study@gmail.com if you are willing to participate!

Spiritbike.study@gmail.co

Appendix C: Subject Consent Form

Consent Form

I, _____, agree to participate in research investigating the lower extremity power output during a single-leg hop test, double-leg jump test, double-leg counterforce Sargent's vertical jump test, and the Spirit MU100 upright cycle ergometer. This study is being conducted by J. Tyler Adams, Gunnar Mendiola, Joseph Brown, Ryan Sullivan, and Cody Williams of the Armstrong State University Physical Therapy Department (912- 344-2580). It has been explained to me that I must first verify that I have had no lower extremity and/or lumbar pain (0/10 on an NPRS scale) during the last 14 calendar days. I will then either perform varied conditions of the single hop test**,** the double-leg jump, and the double-leg counterforce Sargent's vertical jump in a randomized order or the Spirit MU100 upright cycle ergometer test. Whichever tests are not performed during the first session will be performed during the second session. It has also been explained to me that participation in this study is entirely voluntary. I can withdraw my consent at any time without penalty and have the results of participation, to the extent that it can be identified as mine, returned to me, removed from the experiment records, or destroyed.

The following points have been explained to me:

1) The reason for research is to determine if the Spirit MU100 cycle ergometer test is a viable alternative for those whom the single-leg hop test, double-leg jump test, and/or the double-leg counterforce Sargent's vertical jump test are contraindicated.
2) There are no explicit benefits for the subjects to be gained from this study. However, the results of this study may help identify pitfalls that could potentially be prevented in the future.

The procedures are as follows: Subjects will fill out an informed consent form approved by the ASU IRB committee. Subjects will complete a NPRS form. If a subject has experienced pain greater than 0/10, they are excluded from this study. Subjects will fill out a medical questionnaire that screens for various medical conditions and collect information concerning demographics, activity level, height, and weight. The medical questionnaire will identify information concerning pre-existing lumbar spine or lower extremity injuries that would prevent participation in this study. If a subject has any previous lumbar spine or lower extremity surgeries, they will be excluded from this study. The data collection period consists of two sessions that last approximately one hour to one hour and a quarter (60-75 minutes). The hop and jump tests will be performed during one session and the cycle test will be performed during another session; the order of the sessions will be randomized as well as the order of the hop and jump tests. The subject will receive a demonstration on how to perform the assigned test and will be monitored by the researchers throughout the warm-up and testing period to ensure safety. The subject will perform a 5-minute total body warm-up prior to testing using either a bike, elliptical, or treadmill. The <u>single-leg hop test</u>: The subject will then perform 4 gradient warm-up hops, then 12 maximal effort single-leg hops taking off and landing on the same leg and taking off and landing on the opposite leg. <u>Double-Leg Jump</u>: The subject will perform 4 gradient warm-up hops, then 3 double-leg jumps. <u>Sargent's Vertical Jump</u>: The subject will perform 4 gradient warm-up jumps, then 3 vertical jumps.

The <u>Spirit MU100 cycle ergometer test</u>: The subject will perform a 5-minute warm-up on the bike (cycle) with a self-selected cadence. During the warm-up, three 5-second sprints will be performed at 2, 3, and 4 minutes. The testing procedure will follow an incremental sprint progression. Three trials of 100% effort sprint for 20 seconds each will be conducted with the maximum power output recorded.

3) The Armstrong State University Institutional Review Board has approved this research study. The discomfort or stress that may be faced during this research is mild muscle or joint soreness during or after the testing period.
4) No risks are foreseen. If the risk of injury is foreseen, through the use of screening instruments and procedures, the investigators will exclude any potential subject from the study.
5) The results of this participation will be confidential, and will not be released in an individually identifiable form without my prior consent, unless required by law.
6) The investigator will answer any further questions about the research, either now or during the course of the project.

_____

_____

Signature of Investigator Signature of Participant

Date: _____

PLEASE SIGN BOTH COPIES OF THIS FORM. KEEP ONE AND RETURN THE OTHER TO THE INVESTIGATOR. Research at Armstrong State University that involves human participants is carried out under the oversight of the Institutional Review Board. Study data will be maintained for 3 years after completion and will be disposed of by Dr. Frank A. Glenn using a cross-cut shredder and place in a secure recycling bin appropriate for protection of PII/PHI. Questions or problems regarding these activities should be addressed to Donna R. Brooks, Ph.D, Chair, IRB. Telephone: 912-344-2589

Appendix D: Subject Intake Form

The Biodynamics and Human Performance Center at Armstrong Atlantic State University
MEDICAL HISTORY FOR RESEARCH

Today's Date: _____/_____/_____ Study Code/Participant Number _____

Personal Information

Age:_____ Date of Birth: _____/_____/_____ Sex:_____ Dominant Leg: L R

Emergency Information

Do you have medical alert identification? _____ YES _____NO
If YES, where is it located? _____

Current Medications (include ALL medications)

Name of Drug	Dosage; Times/day	Why are you on this drug?
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Hospitalizations

Please list the last three (3) times you have been ill (sick) enough to see a physician, been hospitalized or had surgery.

When?	What was done (surgery, etc.)?	Why was this done?
_____	_____	_____
_____	_____	_____
_____	_____	_____

Family History

Have any members of your immediate family had, or currently have, any of the following?

	Heart	Sudden	Pulmonary	Age of

	Disease	Stroke	Diabetes	Death	Disease	onset
Mother	_____	_____	_____	_____	_____	_____
Father	_____	_____	_____	_____	_____	_____
Sisters	_____	_____	_____	_____	_____	_____
Brothers	_____	_____	_____	_____	_____	_____
Aunts/Uncles	_____	_____	_____	_____	_____	_____
Grandparents	_____	_____	_____	_____	_____	_____
Don't know	_____	_____	_____	_____	_____	_____

Personal Medical History

Do you have any known allergies? _____ YES _____NO If YES, please explain:_____

_____

Do you use tobacco products? _____YES _____NO If YES, please describe product used (cigarettes, pipe, dip, etc.), how often per day (packs, bowls, etc.) and how long you have been a tobacco user (years):

_____

What is your cholesterol level? _____ mg/dl _____don't know

What is your *resting* blood pressure? _____ mm Hg _____ don't know

Please check the following disease conditions that you **had** or currently **have**:

____ High blood pressure	____ Aneurysm	____ Abnormal chest X-ray
____ High blood cholesterol	____ Anemia	____ Asthma
____ High blood triglycerides	____ Diabetes	____ Emphysema
____ Angina pectoris	____ Jaundice	____ Bronchitis
____ Heart attack	____ Hepatitis	____ Thyroid problems
____ Heart surgery (catheter, bypass)	____ Infectious mononucleosis	____ Hernia
____ Heart failure	____ Phlebitis	____ Cancer
____ Heart murmur	____ Gout	____ Epilepsy or seizures
____ Stroke/transient ischemia attacks	____ Kidney stones	____ Prostate problem
____ Rheumatic fever	____ Urinary tract infections	____ Osteoporosis
____ Arteriosclerosis	____ Emotional disorder (depression, etc.)	____ Eating disorder

Please provide dates and explanation to any of the above which you checked: _____

_____

Have you experienced, or do you currently experience any of the following on a *recurring* basis?

At rest:	YES	NO	**During exertion:**	YES	NO
Shortness of breath	____	____		____	____
Dizziness, lightheadedness, fainting	____	____		____	____
Daily coughing	____	____		____	____
Discomfort in the chest, jaw, neck or arms	____	____		____	____
(pressure, pain, heaviness, burning, numbness)	____	____		____	____
Skipped heart beats or palpitations	____	____		____	____
Rapid heart rate	____	____		____	____
Joint soreness	____	____		____	____
Joint swelling	____	____		____	____
Slurring or loss of speech	____	____		____	____
Unusually nervous or anxious	____	____		____	____
Sudden numbness or tingling	____	____		____	____
Loss of feeling in an extremity	____	____		____	____
Blurring of vision	____	____		____	____

If YES to any of the above, please explain:

_____

_____

_____

Orthopedic/Musculoskeletal Injuries

Please check the following disease or conditions which you had or currently have:

____ Stiff or painful muscles
____ Swollen joints
____ Painful feet
____ Severe muscle strain
____ Limited range of motion in any joint
____ Bursitis
____ Depth perception impairments
____ Muscle weakness
____ Amputation
____ Fractures or dislocations
____ Tennis elbow
____ Torn ligaments
____ Pinched nerve
____ "Trick" knee/knee injury
____ Head injury
____ Shoulder injury
____ Ankle injury
____ Whiplash or neck injury
____ Slipped disc
____ curvature of spine

Do any of the above limit your ability to exercise? _____ YES _____NO If YES to any of the above, please explain:

_____

_____

Activity History

Please list any physical or recreational activities that you *currently do* or *have done* on a regular basis.

Activity	Frequency (days/week)	Time (min/session)	How long (years)
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Questionnaire

Today's Date: _____/_____/_____ Study Code/Participant Number _____

Q: Have you had any previous lower extremity (low back, hip, knee, ankle, foot, etc.) injuries or surgeries? If so, please indicate type of injury or surgery and the year.

_____
_____
_____
_____

Q: Are you currently experiencing any pain in the low back, hip, knee, ankle, or foot? If so, please indicate location of pain along with type of pain (achey, sharp, dull, etc.).

_____
_____
_____
_____

Q: Are you currently seeking treatment from a health professional regarding pain in the low back, hip, knee, ankle, or foot?

_____
_____
_____

Appendix E: Script for test protocol

Participant, we would first like to thank you for participating in our research study. This study will consist of two meeting times, one today and one more 5-7 days from now. During the meeting times, one session will measure power output on a stationary bike, while the other session will measure power output by performing two styles of hop tests and a vertical jump. The purpose of this study is to compare the data between the different types of tests, so we ask that you perform all of the tests to the best of your capabilities.

Single Leg Hop:

- Participant, I will first read you the directions to the single leg hop and once I am finished reading the directions we can begin the study and I will direct you as needed.
    - Place dominant foot at the base of the measuring tape with your toe at the "zero" mark
    - Raise non-dominant foot off of the floor, bringing it behind you, and balance on dominant foot
    - Now prepare yourself to perform a single leg hop.
    - The plan here is to hop as far as possible, landing on your dominant foot and maintain balance in order to stand upright on the leg that lands.
    - Be certain not to touchdown or brace yourself with the non-dominant leg upon landing or when standing up form landing.
    - Once you have maintained your balance for 2 full seconds on the leg that lands, you are then allowed to place the other leg on the ground.
- Participant, we will first perform a gradient increase on your attempts.
    - We ask that you perform 3 single leg hops: one at 25%, one at 50%, and one at 75% of your max effort.
    - You will take a 10 second break between each hop.
- Participant, after completing the gradient warm-up, we will then perform your max attempts.
    - We ask that you perform 3 max single leg hops at 100% of your max effort.
    - You will take a 10 second rest break between each attempt.
- Participant, do you have any questions?
    - If no questions, then proceed to perform the test.
- When you are ready, push off of your dominant leg and jump forward as far as you possibly can, while landing on your dominant leg only.
- Once 3 recordable max trials have been completed, we will then switch to your non-dominant leg and perform the same tasks as done on the dominant leg.

- **2 Minute Rest Break Between Tests**

Cross-Over Hop:

- Participant, I will first read you the directions to the single leg hop and once I am finished reading the directions we can begin the study and I will direct you as needed.
    - Place dominant foot at the base of the measuring tape with your toe at the "zero" mark
    - Raise non-dominant foot off of the floor, bringing it behind you, and balance on dominant foot
    - Now prepare yourself to perform a single leg cross-over hop.
    - The plan here is to hop as far as possible, landing on the opposite foot and maintain balance in order to stand upright on the leg that lands.
    - Be certain not to touchdown or brace yourself with the dominant leg upon landing or when standing up form landing.
    - Once you have maintained your balance for 2 full seconds on the leg that lands, you are then allowed to place the other leg on the ground.
- Participant, we will first perform a gradient increase on your attempts.
    - We ask that you perform 3 single leg hops: one at 25%, one at 50%, and one at 75% of your max effort.
    - You will take a 10 second break between each hop.
- Participant, after completing the gradient warm-up, we will then perform your max attempts.
    - We ask that you perform 3 max single leg hops at 100% of your max effort.
    - You will take a 10 second rest break between each attempt.
- Participant, do you have any questions?
    - If no questions, then proceed to perform the test.
- When you are ready, push off of your dominant leg and jump forward as far as you possibly can, while landing on your dominant leg only.
- Once 3 suitable max trials have been completed, we will then switch to your non-dominant leg and perform the same tasks as done on the dominant leg.

- **2 Minute Rest Break Between Tests**

Sargent's Vertical Jump:

- Participant's max one arm reach height will first be measured and recorded against a stationary wall with pre-measurements.
- In this test, you will try and jump from a stationary position as high as you can.
    - Place both of your feet in the starting position
    - When you are ready, jump as high as you can and with your dominant hand hit the flags on the Vertex
    - Land on both feet safely

- You will be given 30 seconds of rest between each trial while we obtain the measurement and reset the Vertex
- You will perform 3 warm-up jumps at 25%, 50%, and 75% of your maximal effort. After completing this warm-up, you will jump as high as you can 3 separate times.
- Do you have any questions?
- When you are ready, begin with the 25% warm-up.

Bike Testing:
Today we will be measuring power output on the upright bicycle.
BIke on → press start → press display button (on bottom) twice

- Begin with a 5 minute warm-up at level 2 resistance on recumbent bike
- You are allowed a 2 minute rest break before testing starts
- Max trials are sustained for 5-10 seconds
- Men: 10 (25%)→ 15 (50%) → 20 (75%) → max trials
    - 30 second rest breaks between progression
    - 1 minute rest break between max trials
- Women : 4 (25%) → 7 (50%) → 10 (75%) → max trials
    - 30 second rest break between progression
    - 1 minute rest break between max trials
- Max trial RPE progression
    - <16 = increase 5 levels
    - 17-18 = increase 3 levels
    - 19-20 = increase 2 level

1	18W	16	509W	31	1000W
2	61W	17	539W	32	1031W
3	94W	18	577W	33	1057W
4	125W	19	606W	34	1083W
5	155W	20	628W	35	1110W
6	185W	21	656W	36	1143W
7	219W	22	683W	37	1183W
8	253W	23	712W	38	1229W
9	289W	24	746W	39	1268W
10	320W	25	797W	40	1306W
11	357W	26	833W		

12	384W	27	865W		
13	412W	28	905W		
14	446W	29	937W		
15	483W	30	969W		

Appendix F: Tables

1	18W	16	509W	31	1000W
2	61W	17	539W	32	1031W
3	94W	18	577W	33	1057W
4	125W	19	606W	34	1083W
5	155W	20	628W	35	1110W
6	185W	21	656W	36	1143W
7	219W	22	683W	37	1183W
8	253W	23	712W	38	1229W
9	289W	24	746W	39	1268W
10	320W	25	797W	40	1306W
11	357W	26	833W		
12	384W	27	865W		
13	412W	28	905W		
14	446W	29	937W		
15	483W	30	969W		

Table 1. Spirit Bike Resistance Levels with Corresponding Maximum Attainable Power

Appendix G: Figures

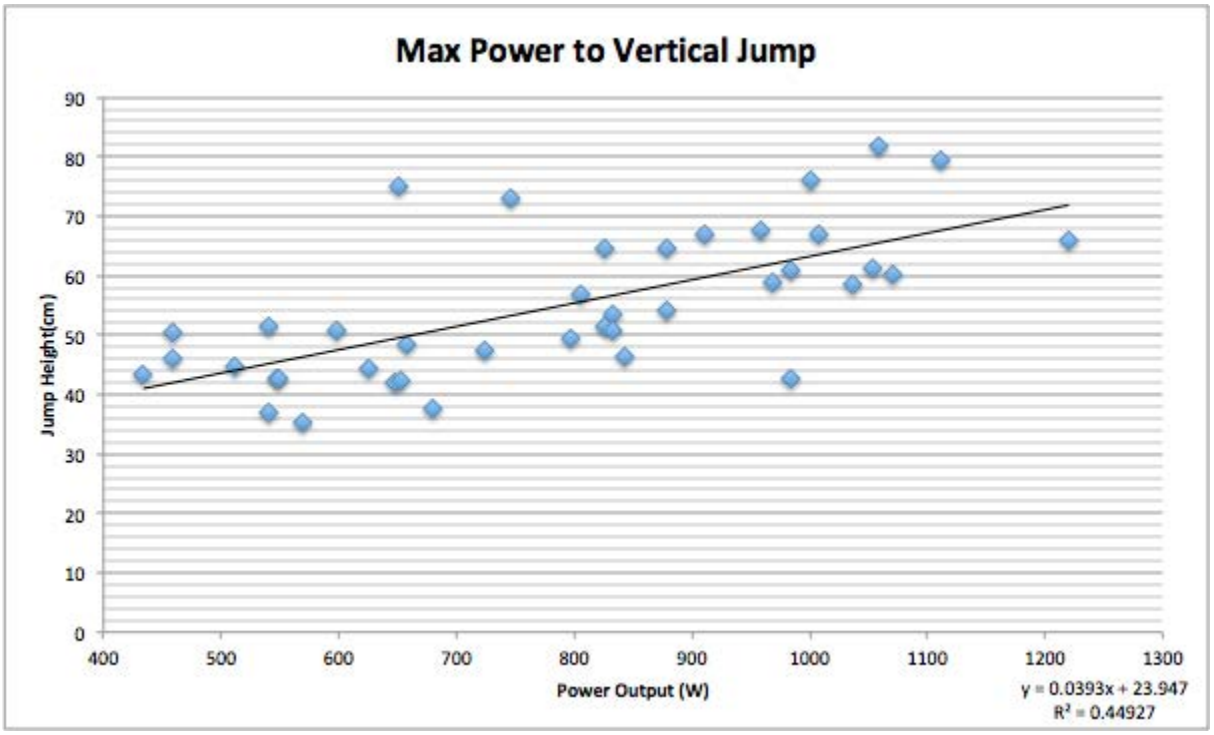

Figure 1. Maximal Power Output plotted against Vertical Jump Height

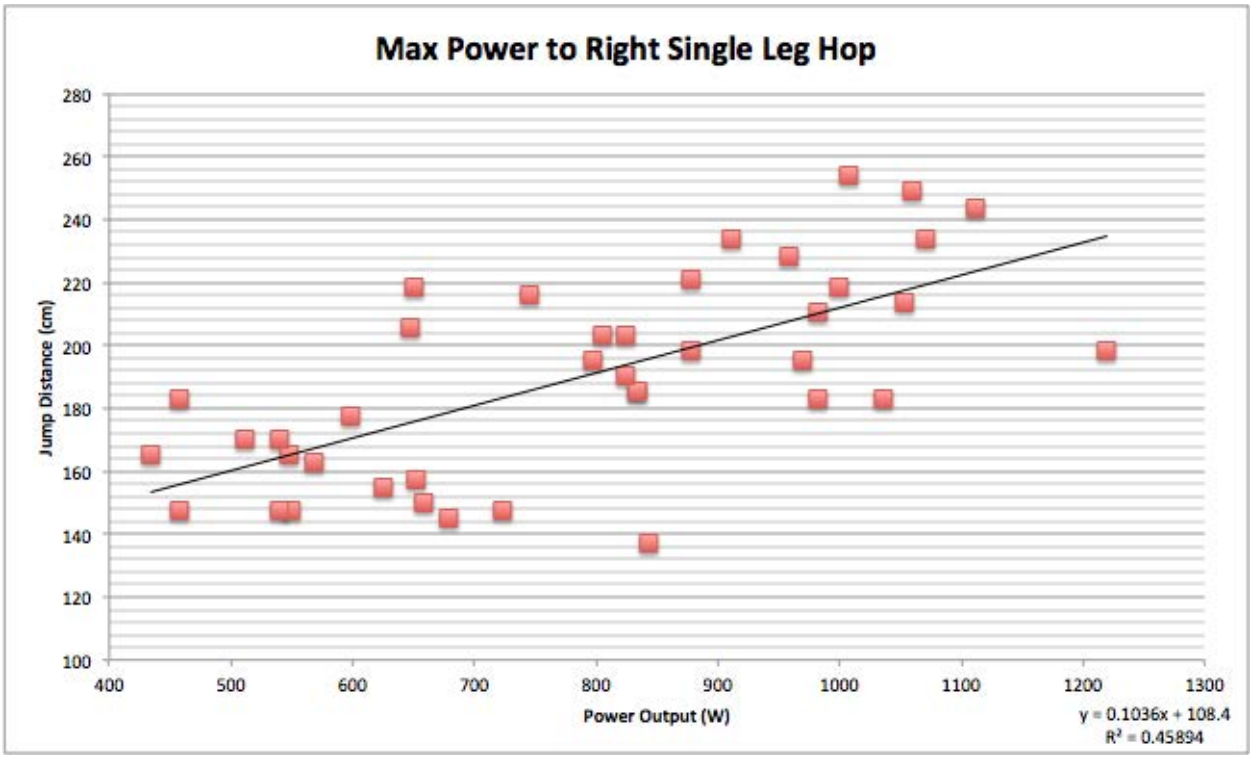

Figure 2. Maximal Power Output plotted against Maximal Distance on Single Leg Hop with the Right Leg

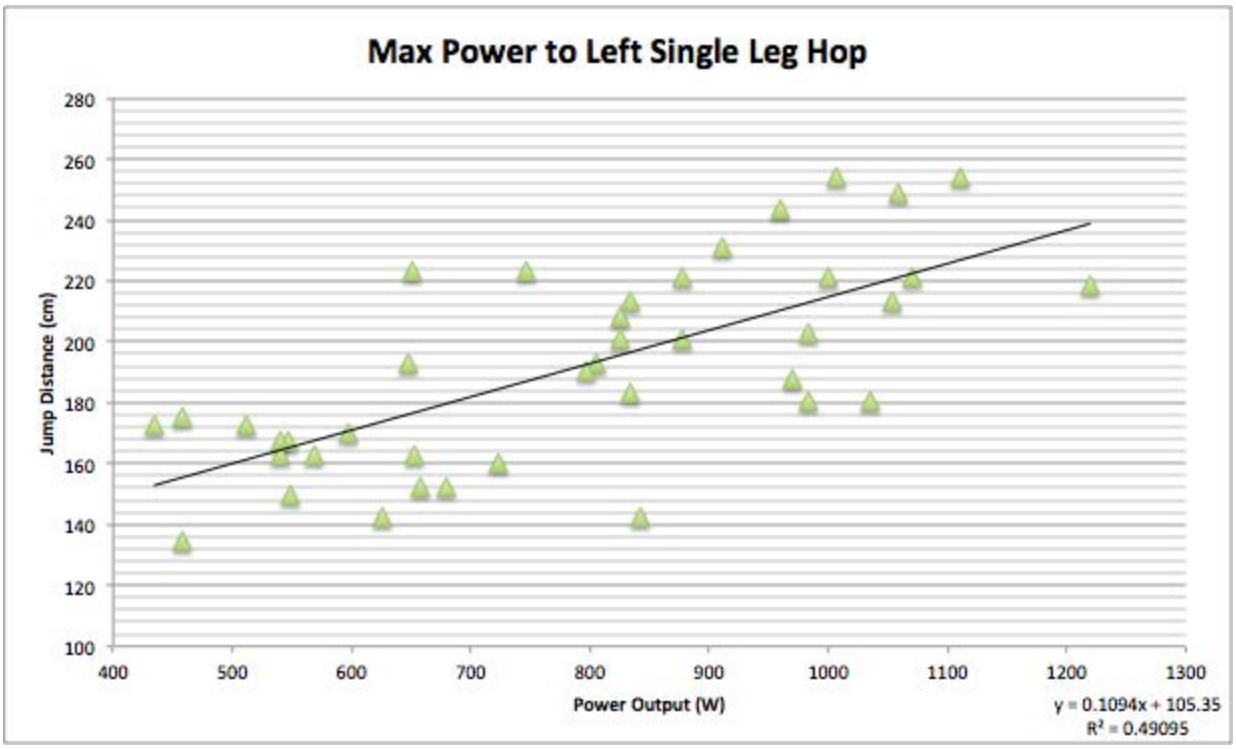

Figure 3. Maximal Power Output plotted against Maximal Distance on Single Leg Hop with the Left Leg

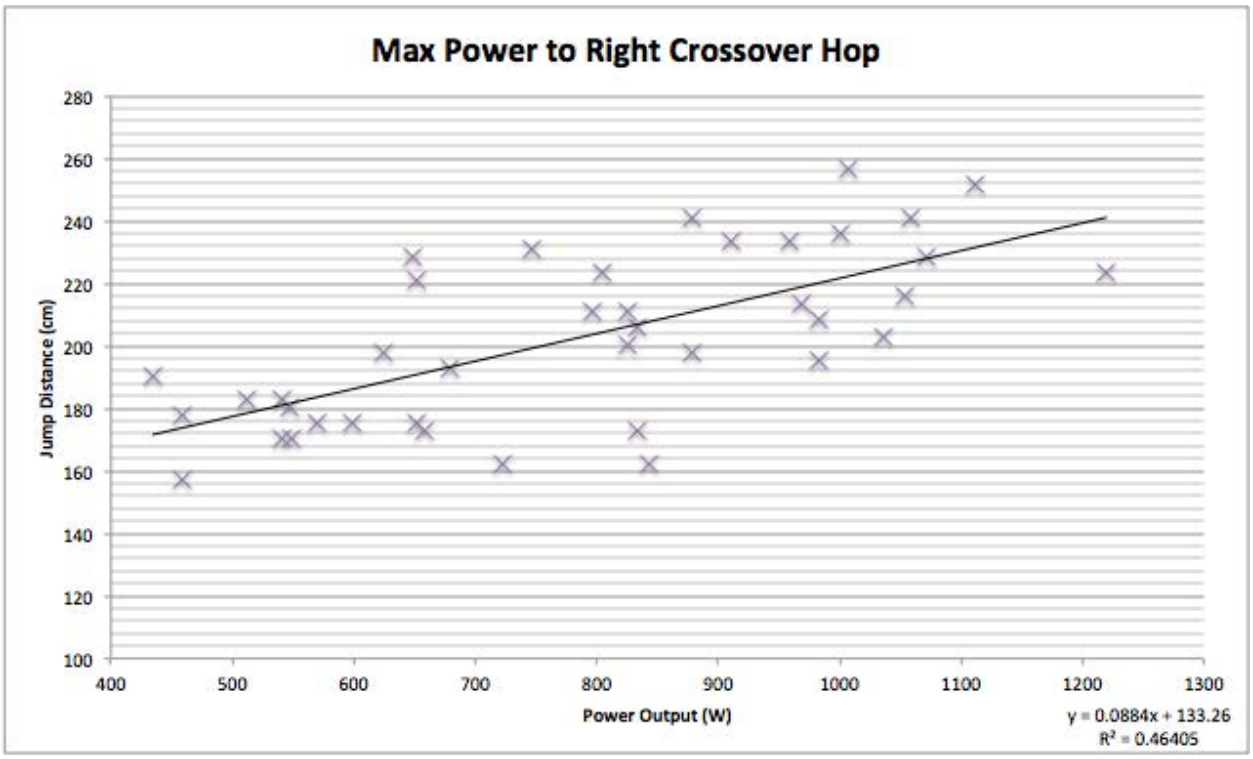

Figure 4. Maximal Power Output plotted against Maximal Distance on Crossover Hop with the Right Leg

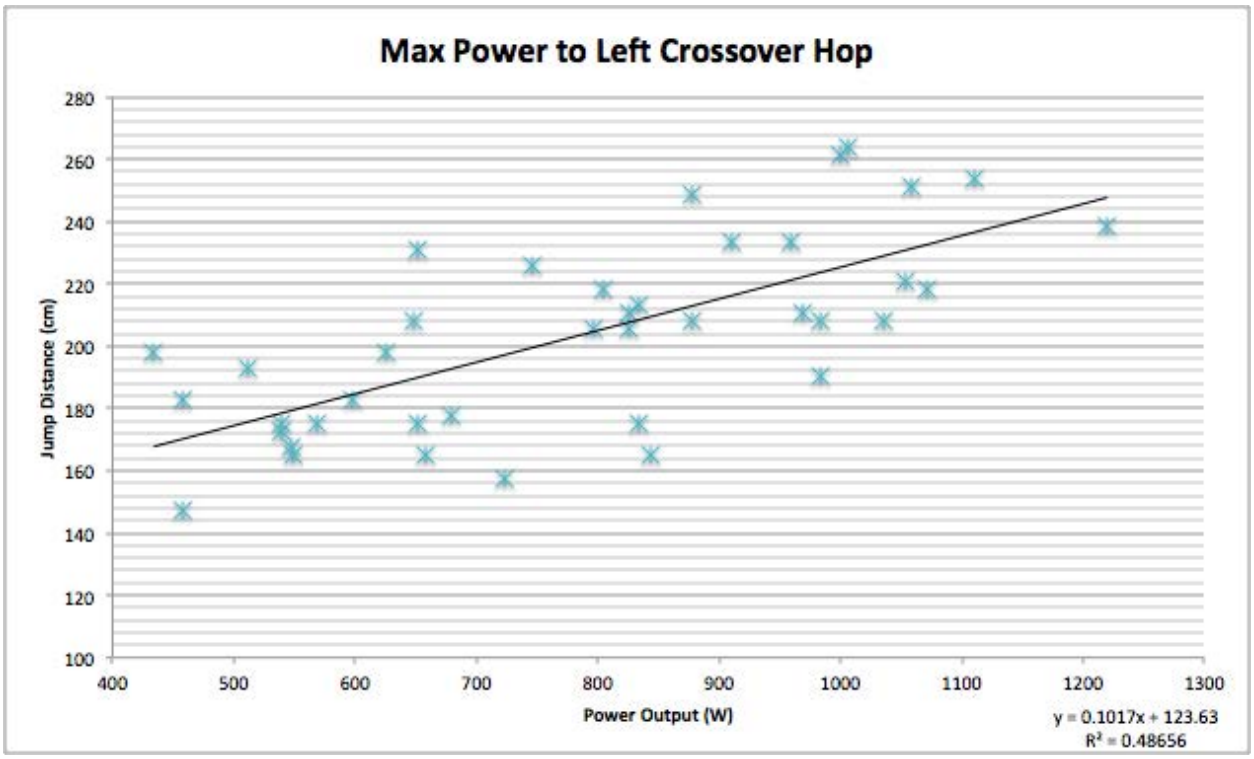

Figure 5. Maximal Power Output plotted against Maximal Distance on Crossover Hop with the Left Leg