

**TITLE:** Factors influencing bicycling behavior

**PROTOCOL VERSION DATE:** Dec 9, 2021

**VERSION:** 1.0

# PRINCIPAL INVESTIGATOR (PI):

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# KEY PERSONNEL

**Name**: [Alaa Ahmed](mailto:alaa@colorado.edu)

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**Role in project**: Co-investigator

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**Role in project**: Co-investigator

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**Role in project**: Co-investigator

# GENERAL RESEARCH STAFF

One research assistant may assist with this protocol. The PI will ensure that the appropriate CITI and protocol-specific training are maintained. General Research Staff’s responsibilities will include distributing flyers, recruiting subjects, and assisting with laboratory testing. They will only perform laboratory testing of subjects with the accompaniment of the PI or Co-investigator.

# OBJECTIVES

Investigate the effect of reward on bicycling movement vigor. Subjects will perform a series of fixed-distance cycling trials at freely selected cadences and power outputs under changing reward conditions. The rider’s chosen bicycling strategy in these conditions will provide information about how they value the reward and effort associated with these movements.

**Research question:** Does reward affect movement vigor in bicycle riders?

**Null hypothesis:** There will be no significant difference in freely chosen cadence nor freely chosen power output in the absence or presence of reward.

# BACKGROUND AND SIGNIFICANCE

**Background.** Choice of movement speed can speak volumes about an individual’s health. Movement speed (i.e., vigor) can be regarded as a trait of individuality, reflecting a willingness to expend effort (Reppert et al., 2018); while in older adults, preferred walking speed correlates with mortality (Stanaway et al., 2011). Importantly, movement speed also features prominently in diseases such as Multiple Sclerosis (MS) and Parkinson’s disease (PD), where a cardinal symptom of these disorders is movement slowness (Jankovic et al., 2008; Montgomery & Nuessen, 1990; Motl et al., 2012; Ferreira et al., 2017; Pellegrino et al., 2018). Studying movement speed and the factors affecting it thus lies at a critical juncture that can expose the underlying processes occurring in the brain through an easily attainable and quantifiable behavioral metric.

In perhaps its simplest form, movement speed can be defined economically: “spending” effort in order to “purchase” a more rewarding bodily state (Shadmehr et al., 2019). This transaction has been modeled as utility, or the “goodness” of a movement, and predicts that the brain should seek to maximize it by optimizing between the effort required with the desire to reach reward sooner (Shadmehr et al., 2019; Shadmehr et al., 2016). Humans will slow down reaching movements (Cos et al., 2011), walking (Hughes & Goldman, 1970), and even eye movements (Yoon et al., 2018) when the effort associated with the movement increases. Contrarily, these movements will all speed up when anticipating some reward (Summerside et al., 2018; Takikawa et al., 2002). While using a common utility helps determine the factors affecting movement speed, it is often difficult to transfer this framework to understanding movement slowness in neurological disorders, like MS and PD, due to an inability to move within the necessary requirements because of disability.

Instead, a common form of movement used in research and physical therapy for neurological disorders like MS and PD is bicycle ergometry (Protas et al., 1996; Ridgel et al., 2009; Tantucci et al., 1996; Valet et al., 2017). Bicycling offers an alternative way to study movement vigor and the changes caused by these diseases; for example, when power output increases, the metabolically optimal pedaling cadence increases linearly, suggesting that bicycling vigor is sensitive to effort (Coast & Welch, 1985; Macintosh et al., 2000). However, there is no research investigating how reward impacts bicycling vigor. Understanding the influence that reward has on bicycling vigor could provide a novel means to study the causes of abnormal movement slowness, as well as a novel means to manipulate and modify treatment of these diseases from a bicycle ergometry context.

**Significance.** Bicycle ergometry is a common form of physical therapy in diseases such as PD and MS; however, there is a dearth of information regarding the causes of movement slowness nor is there a ubiquitous bicycling metric that can be used to track performance improvements. Understanding how reward alters bicycling vigor in healthy adults will provide a starting point for tracking how neurological disorders are altering movement speed. Findings from this study will also better our ability to understand and be able to predict movement behavior and aid in designing interventions to elicit desired behavioral responses by designing the reward-effort landscape appropriately in bicycle ergometry-based physical therapy or in coaching sport.

# PRELIMINARY STUDIES

Reward has consistent, accelerative effects on movement vigor in both non-human animals and humans. Indeed, reaching movements towards rewarding or preferred options tend to comprise shorter reaction times and faster movement speed in both humans (Esteves et al., 2016; Sackaloo et al., 2015; Summerside et al., 2018) and non-human animals (Mosberger et al., 2016; Opris et al., 2011). Even more prevalent is this invigorating effect of reward on saccades. Non-human primates exhibit faster saccades with shorter reaction times in response to rewarded targets (Kawagoe et al., 1998; Kobayashi et al., 2006; Takikawa et al., 2002). Likewise, humans demonstrate invigorated saccades towards rewarding or high-value stimuli (Haith et al., 2012; Manohar et al., 2015, 2017; Milstein & Dorris, 2007; Reppert et al., 2015; Xu-Wilson et al., 2009). Individuals are willing to expend more effort (i.e., move faster) to obtain reward sooner, because it is theorized that the value of reward is temporally discounted (Choi et al., 2014; Shadmehr et al., 2019). A longer delay in procuring reward reduces its subjective value and increases the risk of missing out on the reward in the future, thus it is beneficial to obtain it sooner rather than later.

# RESEARCH STUDY DESIGN

**Summary of Procedures.** We are using a repeated-measures within-subjects design with one factor (Reward) and three levels within each factor (Reward vs. No Reward vs. Time contingent). Participants will be invited to the lab for one day of experimental testing. Participants will complete a single task — riding a bike 400 m — over a series of different conditions on a bicycle ergometer (KICKR, Wahoo Fitness LLC, Atlanta, GA).

Participants will complete a total of 11 trials, consisting of one baseline condition, six replicates of the normal condition, three replicates of the reward condition, and one time-contingent condition (See Figure 1 and Table 1). In the normal condition, participants will complete the 400 m and then be allowed a rest break. In the reward condition, participants will be informed prior to beginning the 400 m that they can choose a candy out of a box upon completion of the distance. After the 400 m, they may select any candy they want but will be required to eat at least one bite of it to control for changes in blood-glucose level across participants. In the time-contingent condition, subjects will be instructed that the faster they complete the 400 m the larger the amount of candy received.

The resistance of the bicycle ergometer is modeled on typical outdoor bicycling conditions on level ground, whereby subjects can freely choose their power output and cadence by changing gear. Altogether, the familiarization and experimental trials will take approximately 1 hour in total, with participants only cycling for less than half the time. Most of the time will be spent resting between trials. In the experimental trials (9 normal/reward trials + 1 time-contingent trial), participants will cycle a total of 4 km, or about 2.5 mi in total. The entire experiment is expected to take no more than 2 hours, likely closer to 1.5 hours on average based on pilot testing.

The estimated duration of the study (recruitment through data analysis) is 1 year allowing for current and possible future delays due to the continued outbreak of COVID-19 and its variants.



**Figure 1.** A diagram showing the three conditions (A-C) to be tested.

**Data Analysis.** We performed a conventional power analysis (alpha = 0.05, power = 90%) to determine that a minimum sample size of 23 will be required to detect an effect size of 0.8 at our desired power. A sample size of 23 also allows us to detect effect sizes as small as 0.44.

The primary outcome variables will be cadence, simulated velocity, crank power, and time to complete the 400 m, which are all measured by a crank-based power meter (Quarq DZero, SRAM LLC, Chicago, IL) and recorded by a cycling computer (Edge 1000, Garmin Ltd, Olathe, KS). Repeated-measures ANOVA and linear mixed effects models will be used to compare and estimate the changes of the outcome variables under different rewards.

| Name of procedure/instrument/tool | Purpose (i.e., what data is being collected?) |
| --- | --- |
| ACSM health screening form |  |
| Wahoo KICKR bicycle trainer | Provides apparatus for stationary cycling under different modes of resistance and motion. |
| Apple iPhone | Runs Wahoo Fitness application. |
| Candy basket | Contains individually wrapped gifts for the subject to choose from. |
| Quarq DZero crank-based power meter | Measures crank angular velocity, torque, and power at 1 Hz. |
| Garmin Edge 1000 cycling computer | Collects and stores data from the Quarq power meter at 1 Hz. Provides visual feedback of distance ridden (m) to rider. |
| Specialized Chisel bicycle | Hardtail mountain bike used for stationary riding in conjunction with Wahoo trainer. |

# FUNDING

This project will not receive financial support.

# ABOUT THE SUBJECTS

We plan to recruit and enroll 30 participants. Based on our experience, we anticipate that <10 % of participants who are enrolled will elect to withdraw or be unable to complete the protocol due to the intensity of cycling. However, to be conservative, we seek permission to enroll up to 30 participants. Participants will be adults (between 18-40 years of age), of any sex, and any ethnicity.

These participants will be recruited from the general campus population. Although it is not likely that different gender or minority populations would affect the results of the proposed research, we will recruit subjects from the surrounding Boulder area and expect that the distribution of minorities among subjects will likely match the distribution of minorities in the Boulder population: American Indian or Alaskan Native 1 %, Asian or Pacific Islander 4 %, Black or African American 1 %, Hispanic or Latino 5 %. We anticipate the subjects will be evenly distributed between male and female subjects.

We will screen for apparently healthy adults who meet the guidelines set forth by the American College of Sports Medicine (ACSM, 2017). The latest American College of Sports Medicine guideline indicates that a medical exam and diagnostic exercise testing are not warranted prior to beginning a vigorous exercise program for apparently healthy individuals who already participate in regular exercise and do not have any signs or symptoms of cardiovascular, metabolic, or renal disease. We will use a screening form to determine if these criteria are met (see Screening Form included with eRA submission).

The day prior to attending the laboratory for testing, participants will be screened over the phone for COVID-19 infection and exposure according to the procedures outlined by the Department of Integrative Physiology.

Inclusion criteria:

* Between 18-40 years of age
* Apparently healthy and cleared to participate in physical activity

Exclusion criteria:

* Not able to understand simple directions in English (assessed by their ability to respond to questions posed when in the laboratory.
* Physically active in a weight-bearing exercise three or more times per week over the past year (walking is considered a weight-bearing exercise; this will be assessed with the first question, Q1).
* Major musculoskeletal impairment, orthopedic implants, fractures of the extremities/orthopedic surgeries in the past year that would impair the ability to generate useful data.
* Major neurological disease (e.g., stroke, Parkinson’s Disease), which may increase risk and/or impair ability to generate useful data.
* Major vestibular diseases or disorders which may increase fall risk and/or impair ability to generate useful data.
* Regular episodes of dizziness or fainting which may increase fall risk.
* Other conditions, chronic illnesses, or medications that could impair ability to complete the tasks. Medications warranting exclusion are those that may cause dizziness or impaired movement reflexes (i.e., antidepressants, sedatives, antihypertensive or ototoxic medication).
* Any allergies to chocolate or nuts.

| Subject Population(s) | Number to be enrolled in each group |
| --- | --- |
| Apparently healthy adults (18-40 y/o) | 30 |

# VULNERABLE POPULATIONS

We will not enroll any vulnerable populations.

Students or staff who report to the investigators will not be specifically targeted for recruitment. These individuals may be enrolled and tested if they respond to the email or flyer recruitment materials distributed among the campus and Boulder communities.

# RECRUITMENT METHODS

**Recruitment Process.** The candidate population for this study will consist of volunteers recruited through word of mouth by the investigators, flyers, Buff Bulletin, media posts, and email (Flyer, sample media post, and sample email attached). Flyers will be posted around the CU campus. Media posts will be advertised through the CU Boulder Today website. The flyer will also be emailed to friends, local cycling clubs/message boards, etc.

The recruitment materials provide an email address for the study (culocomotionlab@gmail.com). The investigators will monitor that email address and reply to candidate participants initially via email.

**Recruitment Screening.** After obtaining verbal consent, a testing session will be scheduled. Upon arrival, we will screen participants for COVID-19 infection, exposure, and risk using the attached screening form titled “IPHY Human Subjects Research Participant COVID-19 Visit Screening”.

The investigator will examine the subject’s answers on each screening form and determine if they are eligible before asking them to read and complete the consent form.

**Avoiding undue influence/coercion.**

* The primary recruitment methods will occur via IRB approved flyers, ads, and scripts.
* To avoid any potential teacher-student power differentials or feelings of obligation, current students of the PI or any co-investigator will not be recruited at that time.
* The research does not involve deception.
* The research does not involve participation of minors.
* Inclusion criteria requires that the subjects be English-speaking to avoid unnecessary misunderstandings.
* Emphasis will be put on reminding the subject they may withdraw from the study at any time.

| List recruitment methods/materials and attach a copy of each in eRA |
| --- |
| 1. Flyer |
| 1. Media post |
| 1. Email/phone script |
| 1. Buff Bulletin |

# COMPENSATION

Participants will be compensated for their time and effort with candy bars. Participants will receive one candy bar after each “reward” and “time-contingent” trial. The treats will consist of a selection of sealed, fun-sized candy bars that have a low potential for causing allergies. Participants will receive the candy bars even if they choose to withdraw before completing the study protocol.

# INFORMED CONSENT

Candidate participants will be verbally informed of the requirements and goals of the study. If they are still interested in participating, consent forms will be read and signed by the participant before being involved in the study.

Upon reporting to the laboratory and after completing the test screening form, participants will be provided with a consent form and allowed to read it in a private room with just the investigators present. After the participant reads the form, an investigator will ask them if they have any questions and answer any questions. The investigator will then follow up with a few questions to get some idea as to whether the subject read the consent form (e.g., “What will we be measuring in this experiment?”). If the subject’s responses seem vague, the investigator will ask the subject to re-read the consent form and the investigator will explain any uncertainties. Participants will be given as much time as required to decide on participation and reminded that they may also leave the study at any time.

# PROCEDURES

**A.) Inclusion and Consent.** Before coming to the laboratory, participants will be told to fast for approximately 2 hours before the study. Participants will report to the front steps of the Clare Small building. All in-person screening and testing procedures will take place at the Locomotion Laboratory within the Clare Small building. Participants will be handed a sanitized clipboard and pen to fill out the screening and consent forms. Researchers and participants will be required to maintain social distancing, wear a face mask, and frequently disinfect their hands with an antibacterial gel.

While taking the necessary precautions to minimize the risk of spreading COVID-19, participants will complete the screening and consent forms, and then begin the experimental procedure.

Testing will be performed on a test bicycle (Chisel, Specialized Bicycle Components, Inc., Morgan Hill, CA, USA) mounted in an inertial-load bicycle trainer. The frame size and geometry of the bicycle will be matched to the participant’s height. Power and cadence will be recorded by a cycling computer mounted to the handlebar (Edge 1000, Garmin Ltd, Olathe, KA, USA). The bike will be equipped with a crank-based mechanical power meter (Quarq DZero, SRAM, Corp, Chicago, IL, USA) with 172.5 mm long cranks. The power meter will be calibrated prior to each testing session.

**B.) Familiarization.** Participants will begin with a brief setup period in which the researcher will adjust the bicycle (i.e., seat height) to ensure it is fitted properly, inform the individual about the bicycle, and teach them about shifting gears.

Participants will then undergo a familiarization period while riding the bicycle. They will shift into the easiest gear and then pedal the bicycle for approximately 20 seconds in each of the 11 gears on the bike. The researcher will keep time and instruct participants to “shift” after each 20 second period. After they have experienced 20 seconds in each of the gears, the participants will then have a free period of 30 seconds to ride the bike however they like.

The participants will then shift back into the easiest gear and perform a ramp-up familiarization. The researchers will inform the participants that each trial in the main experiment will begin in this easiest gear, and that the purpose of this practice ramp-up is to simulate the beginning of an experimental trial. The researchers will indicate the start by saying, “Ready, set, go.” After the indication to go, the participant is free to begin pedaling and shifting to whichever gear combination feels most comfortable to them. After this simulated ramp-up, participants will then be instructed to keep pedaling however they feel most comfortable for 10 min. The purpose of this 10 min period is to further familiarize the participants with the bicycle and with the sensation of riding a bicycle on the Wahoo trainer, while also doubling as a physiological warm-up. Because of the sensitive nature of our measures to the specific instructions provided, we have a script we will follow preceding each of these phases:

* **Before beginning any trials:** *“This experiment will take 1 hour. You will complete a series of quarter mile (400 m, one lap around a track) cycling trials. Each trial will start with the easiest gear, but once the trial begins you can change gears however you like. Please ensure your hands are on the handlebar for the duration of the trial. To reiterate, this is not an assessment of your fitness or cycling ability.”*
* **Familiarization*:*** *“This is the familiarization phase to help you get accustomed to the different gears. You will spend 20 seconds riding in each gear. We’ll let you know when the 20 seconds is up, and you can switch to the next gear. Once you have experienced all the gears, we will give you 30 seconds to explore all the gears, unrestricted.”*
* **Practice ramp-up:** *“Practice the first 30 seconds of a trial where you will ramp up and change to your preferred gear.”*
* **Extended warm-up:** *“This is a warm-up trial. In this trial, you will ride for 10 min however you like. You will start in the easiest gear.”*

**C.) Cycling Testing with Reward.** After familiarization, the primary protocol will begin. Participants will not be informed of how many trials they will complete or have remaining, only that the entire protocol will take about 1 hour to complete.

Participants will begin with a baseline trial. They will be instructed to start in the easiest gear and then be asked to ride a quarter mile (400 m) however they like. The only feedback provided to the participant for this trial and all following trials will be distance, in meters, displayed on the cycling computer mounted to the handlebars of the bike.

After baseline, participants will then perform a series of 9 “normal” and “reward” trials in the following order:

| **Normal 1** | **Normal 2** | **Reward 1** | **Normal 3** | **Normal 4** | **Reward 2** | **Normal 5** | **Normal 6** | **Reward 3** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **5 min** | **5 min** | **5 min** | **5 min** | **5 min** | **5 min** | **5 min** | **5 min** | **5 min** |

Each of these “normal” and “reward” trials will be 400 m trials. In the “normal” trials, participants will complete the 400 m and then rest. During the “reward” trial, a box full of candy bars will be presented to the participant. They will be instructed that, upon completion of this 400 m trial, they will be able to select a candy bar of their choosing from the box. After the trial, we will instruct participants that they must eat at least one bite of their candy bar to moderately control for blood-glucose level effects. Participants will not be allowed to eat any of their previously selected candy bar following a “normal” trial. Each trial (riding + rest) will be a total of 5 min, and a timer will be started by the researcher at the beginning of each trial to keep the time for each trial constant.

Lastly, following this series of “normal” and “reward” trials, participants will complete a “time trial” or “time-contingent” trial. In this trial, participants will be instructed that, “This is your final 400 m trial. The faster you go, the more candy bars you will receive.” In this case, the participant’s reward is seemingly contingent on their performance. Afterwards, we will always tell the participant that they earned the maximum amount of reward and may select 2 candy bars.

Because of the sensitive nature of our measures to the specific instructions provided, we have a verbal script to use preceding each of these trial types:

* **Baseline:** *“This is a baseline trial. In this trial, you will ride a quarter mile (400 m) however you like. You will start in the easiest gear.”*
* **Normal trial:** *“For this next quarter mile, after completing this trial you will get a rest break.”*
* **Reward trial:** *“For completing this trial you will get to choose a candy bar from our selection. After completing this trial, you will get a rest break.”*
* **Post reward trial:** *“That was great! Please select your cand bar. We require you to eat at least 1 bite of the candy bar.”*
* **Before time-contingent trial:** *“This is your final 400 m trial. The faster you go, the more treats you will receive\*.”*
  + \*If asked about performance measurement: *“Your performance is assessed relative to your previous trial completion times.”*
* **Post time-contingent trial:** *“That was great! You earned the maximum and can pick 2 candy bars.”*

**D.) Data Acquisition.** Altogether, the familiarization and experimental tasks will take approximately 1 hour in total, with participants only cycling for less than half the time. Most of the time will be spent resting between trials. In the experimental tasks (9 normal/reward trials + 1 time-contingent trial), participants will cycle a total of 4 km, or about 2.5 mi. The distance cycled in the 10 min warm-up period will be participant dependent. The entire experiment is expected to take no more than 2 hours, likely closer to 1.5 hours on average based on pilot testing.

For all participants, cycling cadence, velocity, power, and time to complete each 400m trial will be measured by a crank-based power meter at 1 Hz and recorded on a cycling computer at 1 Hz. Data will be converted from .fit file type (from the cycling computer) to analyzable .csv format using open-source software (GoldenCheetah, <https://www.goldencheetah.org/>). Data processing and analysis will be performed in MATLAB (R2021b, MathWorks Inc., Natick, MA) and Python (v3.7, [www.python.org](http://www.python.org)).

| Visit # | Procedures/Tools | Location | How much time the visit will take |
| --- | --- | --- | --- |
| Visit 1 | Consent | Locomotion Laboratory, Clare Small Arts & Sciences, 1725 Pleasant St, Boulder, CO 80309-0354, USA | 5 min |
| Fit bike to participant | 5 min |
| Familiarization + Warm-up | 15 min |
| Cycling Testing + Reward | 50 min |

# SPECIMEN MANAGEMENT

N/A

# DATA MANAGEMENT

Confidentiality of personal records will be strictly maintained in all published reports and oral presentations resulting from this study. All participants will be given an alphabetic participant code as an identifier for the study. Participant information will be kept in locked cabinets in a locked office (Temporary Building, room 110) under the supervision of Dr. Rodger Kram. Identifiable data will be shared with no one outside of the immediate research team. Data security for storage and transmission for electronic data stored on desktop computers will be managed via a secure network and password access. Data will be retained indefinitely, but the participant code identifier document (paper) will be destroyed in 1 year via shredding.

# PROVISIONS TO PROTECT THE PRIVACY INTERESTS OF PARTICIPANTS

We do not foresee this study having any significant impact on a participants’ privacy interests. All experiments will take place on the CU Boulder campus. Only the researchers involved in this study are likely to be present within the laboratory. Subjects will wear the same type of athletic clothing that they would wear when bicycling for exercise in public. We inform the subject in the consent form that they cannot expect complete privacy during the conduct of the study.

# WITHDRAWAL OF PARTICIPANTS

We do not anticipate any circumstances under which participants will be withdrawn without their consent. Participants who choose to withdraw before completing the experiments will be freely allowed to do so.

# RISKS TO PARTICIPANTS

Exercise can cause fatigue and minor discomfort. About 4 in 10,000 average people have chest pain or a heart attack and 1 in 10,000 people die during an exercise test. Fortunately, for an adult without overt heart disease, who exercises regularly, the risk of a cardiac event (heart attack) during exercise is very small, less than 1 chance in every 400,000 person-hours of exercising (approximately equal to exercising for 45 years, 24 hours per day).

Participants could be exposed to COVID-19 during testing. The risk of serious symptoms, hospitalization, and death will be mitigated by following the CDC, CU-RIO R2R, and IPHY guidelines. Participants who are deemed eligible for our study will have been screened to be healthy adults who self-report being symptom-free and not having close contact with any persons confirmed to have COVID-19. Thus, our participants are deemed low-risk for developing serious symptoms due to COVID-19.

# MANAGEMENT OF RISKS

Bicycling on an ergometer is very low risk, as the rider is not moving relative to their surroundings. Thus, in the unlikely event of a fall, the rider will not collide with any objects with a substantial horizontal velocity. Thus, we are confident that these experiments do not present any undue risk to the participants or investigators.

If a participant experiences a non-life-threatening injury (e.g., a cut, scratch, or wrist sprain) that requires medical treatment, the experimenters will provide reasonable assistance in getting the subject to Wardenburg Health Center, or Urgent Care at the Boulder Medical Center. Professor Kram has more than 25 years of experience conducting these types of experiments and has never had a subject experience a serious injury during testing.

In the unlikely event of a life-threatening event (e.g., cardiac arrest), the investigator(s) would call 911, begin CPR, and await EMS arrival. Accordingly, all investigators are trained in CPR and AED and at least one investigator will be present during these experiments. A First Aid Kit and AED are always kept within the Locomotion Laboratory.

# POTENTIAL BENEFITS

The only direct benefit is that the participants will experience a moderate amount of physical exercise. This is non-clinical research that will provide new information regarding the effect of reward on movement vigor during seated cycling. The results of this study will further our understanding of how people move and the value they assign to the goal of the movement.

# PROVISIONS TO MONITOR THE DATA FOR THE SAFETY OF PARTICIPANTS

The proposed study is short-term in nature. If a participant reports an injury or substantive discomfort during or after participating, we will review our experimental procedures and take action to minimize/eliminate the risk of such problems.

# MEDICAL CARE AND COMPENSATION FOR INJURY

Research involves minimal risk

# COST TO PARTICIPANTS

There are no costs to the participants.

# DRUG ADMINISTRATION

N/A

# INVESTIGATIONAL DEVICES

N/A

# COLLABORATIVE STUDIES

N/A

# SHARING OF RESULTS WITH PARTICIPANTS

We intend to prepare the results of this study for presentation at scientific conferences and publication in a scientific journal. In these ways, study results will be made part of the public record and will be made accessible to participants.

# XXVI. REFERENCES

Choi et al., 2014

Coast and Welch, 1985

Cos et al., 2011

Esteves et al., 2016

Ferreira et al., 2017

Haith et al., 2012

Hughes and Goldman, 1970

Jankovic et al., 2008

Kawagoe et al., 1998

Kobayashi et al., 2006

Macintosh et al., 2000

Manohar et al., 2015

Manohar et al., 2017

Milstein and Dorris, 2007

Montgomery and Nuessen, 1990

Mosberger et al., 2016

Motl et al., 2012

Opris et al., 2011

Pellegrino et al., 2018

Protas et al., 1996

Reppert et al., 2015

Reppert et al., 2018

Ridgel et al., 2009

Sackaloo et al., 2015

Shadmehr et al., 2016

Shadmehr et al., 2019

Stanaway et al., 2011

Summerside et al., 2018

Takikawa et al., 2002

Tantucci et al., 1996

Valet et al., 2017

Xu-Wilson et al., 2009

Yoon et al., 2018