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Is There a Correlation Between Rate of Electromyography Rise in the Flexor Carpi Radialis Muscle and Comfortable Gait Speed?

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ABSTRACT

Falls are a leading cause of injury-related deaths in older adults. Although gait speed (a strong predictor of falls) correlates with handgrip strength, its correlation with muscle power (amount of force produced over time) is unknown. Since peak quadriceps rate of force development (RFD) occurs at a submaximal force during ambulation, RFD could be a determinant of gait speed[13]. Quadriceps RFD is a measure of lower extremity power[13], just as handgrip RFD is a measure of upper extremity power. Assuming that RFD is uniform throughout the body, handgrip RFD may also be correlated with gait speed. One method of studying neural input during the initial portion of muscle activation in RFD is through analyzing the rate of electromyography rise (RER) for a specific muscle[12]. **PURPOSE:** To determine whether rate of EMG rise in the flexor carpi radialis muscle (RER_{FCR}) correlates with comfortable gait speed in college-aged adults. **METHODS:** Surface EMG was placed over the right flexor carpi radialis (FCR) to measure handgrip RER_{FCR} from 0 to 75 ms. Gait speed was determined through the 4-Meter Walk Test. **RESULTS:** There is a significant, positive correlation ($p < 0.01$) between comfortable gait speed and RER_{FCR}. **CONCLUSION:** The results show that motor neuron discharge rate plays a role in gait speed. This does not translate to an ability to predict performance on gait speed tasks or assessment of fall risk, but rather serves as a baseline for future investigation to determine whether muscular power contributes to gait speed.

Keywords: Surface electromyography, sEMG; rate of EMG rise; muscle activation; gait speed; fall risk; rate of force development.

Abbreviations: electromyography (EMG), rate of electromyographic rise (RER), flexor carpi radialis (FCR), rate of force development (RFD), National Institute of Health (NIH), first dorsal interosseous (FDI).

INTRODUCTION

One of the biggest dangers plaguing the geriatric population is the risk of experiencing falls. Falls are the leading cause of injury-related death among adults ages 65 and older and one in three seniors can expect to fall at least once a year, with as many as 24% of these falls leading to serious injury from the impact[9]. The subsequent impairments, which include things like hip fractures and brain injuries, can lead to an individual's gait speed to slow down. Though seemingly harmless, a slowed gait speed can prove to be fatal.

Both comfortable and fast gait speed play an important role in understanding the functional capacities and potential health outcomes of older adults. When measured at a comfortable pace, gait speed has been identified as a predictor of adverse health outcomes in the older adult population, including disability, cognitive impairment, institutionalization, falls, and/or mortality[2]. Similarly, a decline in fast gait speed has been shown to correlate with disability regardless of a person's comfortable gait speed[4]. Given its clinical importance, many researchers have become interested in trying to understand the many variables associated with gait speed.

Although the utility of gait speed in determining health risk factors in older adults is unquestionable, there exists a need for an alternative means of obtaining these same data points in nonambulatory adults. Due to its ease of implementation – requiring only a handheld dynamometer for assessment – grip strength has gained plenty of attention in the literature. To take matters even further, gait speed and grip strength has been shown to correlate with one another in measures such as cognitive impairment and decline[7] as well as frailty[10].

Power is a measure of dynamic strength that has been shown to be associated with functional performance even more so than strength is[11]. Despite its functional implications, handgrip power, unlike handgrip strength, has not been explored thoroughly in the literature. The value of understanding the relationship between gait speed and power, could potentially be equally as important. When one thinks about a fall, for instance, one could assume that the muscular strength available to the lower extremities is important for an individual to avoid or minimize the impact of falling. Muscular power, however, could theoretically be of equal value due to its ability to quickly elicit the muscular response needed to produce the required muscular force.

As mentioned earlier, the velocity, or speed, of muscle force production is a key variable when understanding power. One method of analyzing it is by looking at the rate at which a muscle produces force, termed "rate of force development" (RFD)[1]. Much like the RFD in the quadriceps muscles is said to be representative of lower extremity power, the RFD involved in handgrip is representative of upper extremity power. Assuming that RFD is uniform throughout the body, it can be predicted that RFD in handgrip musculature can correlate with gait speed much like RFD in the quadriceps muscles correlates with gait speed.

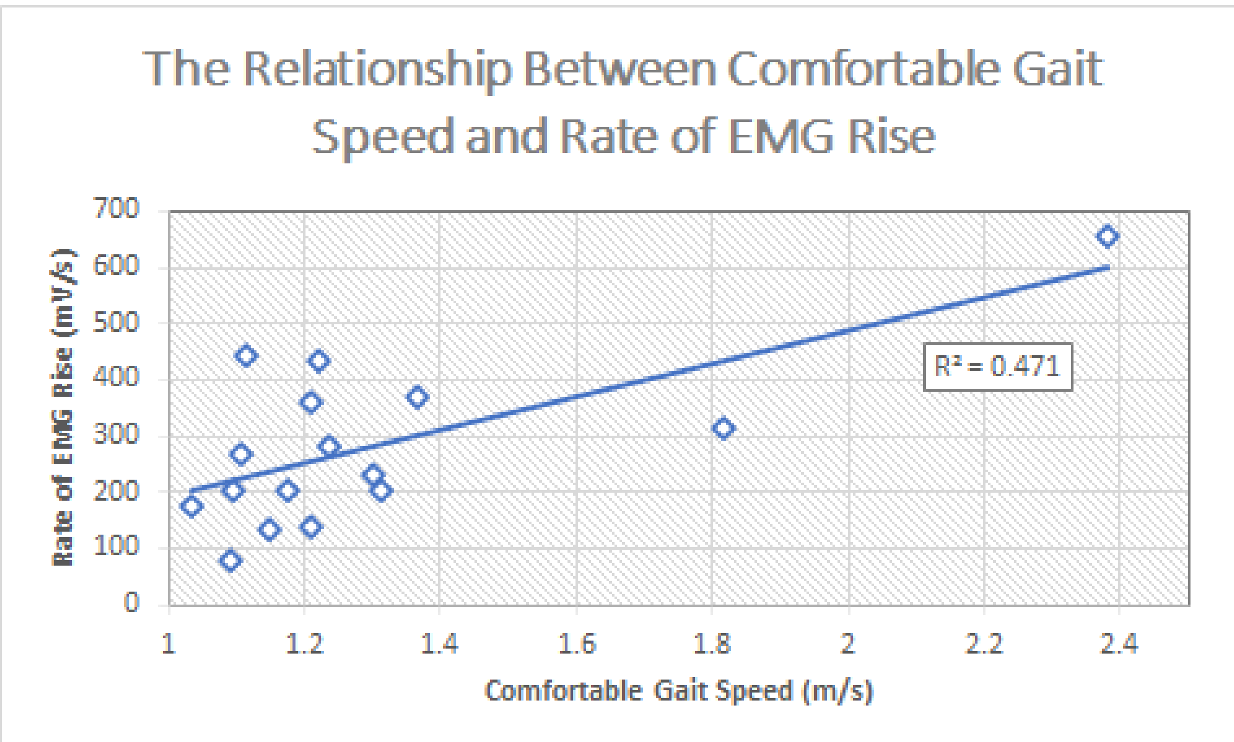
In this study, surface electromyography (sEMG) was used to record the electrical activity of the flexor carpi radialis (FCR) muscle- a prime mover of grip. The slope of EMG data plotted against time is termed "rate of EMG rise" (RER). In essence, RER represents the neural excitation of a specific muscle during the early phases of muscular contraction[1]. Considering that current research suggests there to be a bilinear relationship between RER and RFD[8], this study aimed to explore the relationship between RER and gait speed.

METHODS

Study Design

This study utilized a correlation study design to investigate the relationship between gait speed and rate of EMG rise (RER_{FCR}) as the primary outcome. Secondary analysis was done with demographic data to verify correlations proven in previous research studies. Each participant visited the laboratory one time that was scheduled ahead of time. Participants were sent reminders (via call, text, or email) of their appointment time and to refrain from consuming alcohol or caffeine prior to their visit. Sessions in the laboratory lasted an average of 2 hours. The first hour was utilized to obtain informed consent, demographic information, and gait speed tests. The second hour was used to collect EMG data during grip strength testing. Researchers read instructions from scripts for all tests to standardize data collection so that each participant understood the procedure while minimizing human error. Gait speed tests were completed at the same test area with markers indicating 0m, 2m, 6m, and 8m at consistent intervals to eliminate replication error. Electromyography data was gathered with the same equipment for all participants.

Figure 1. A visual representation of the relationship between comfortable gait speed and rate of electromyography rise in the flexor carpi radialis muscle.



Participants

A total of 17 participants were recruited for this study, but one (Participant 12) was excluded after data collection due to age (n=16). Participants aged 18 years and older were eligible to participate if they could walk at least 20 feet without an assistive device and demonstrate absence of significant cognitive deficits that could impede their ability to follow directions during the assessment. Individuals who had a history of any neurological condition, musculoskeletal disorder, epilepsy, seizures, head trauma, metal implants, heart attack, or cancer were excluded. A physician was consulted for any individuals whose eligibility was unclear due to their medical history after completing a telephone screening. (Addenda 1a and 1b) The University of Central Florida's Institutional Review Board (IRB) approved this study.

The average age of the participants was 23.6±4 years. Participants were split relatively evenly between sexes with F=10 and M=7. Overall, the participants were relatively healthy young adults who exercised an average of 307 minutes per week. (Table 1)

Table 1. Participant Demographic Characteristics

Participant ID	**Age (years)**	**Sex (M/F)**	**Height (cm)**	**Weight (lbs)**	**Ethnicity**	**Amount of Exercise per Week (min)**
001	23	F	65	156	White	60
002	29	F	64.5	136	Asian or Pacific Islander	540
003	32	M	72	194	White	180
004	20	F	67.75	126	Hispanic	240
005	20	F	65.75	126	White	60
006	27	M	72.5	197	Hispanic	150
007	23	F	67	224.4	White	120
008	22	M	66.75	159	Hispanic	300
009	19	F	67	128	Asian or Pacific Islander	90
010	18	M	68.5	148	White	1,320
011	19	F	65.25	128	White	270
013	21	F	61.75	127	Asian or Pacific Islander	360
014	24	M	60.5	188	White	240
015	22	F	70	168	Black	600

Participant ID	Age (years)	Sex (M/F)	Height (cm)	Weight (lbs)	Ethnicity	Amount of Exercise per Week (min)
016	27	F	66.2	143	White	150
017	25	M	63.6	180	Asian or Pacific Islander	240

Gait Speed

The NIH Toolbox® iPad app was used to conduct the 4-meter Walk Gait Speed Test to assess both comfortable and fast gait speed. The participant was asked to walk along a flat, 4-meter course one time, at both their normal and fast gait speeds. One practice trial was allotted for each gait measurement before two test trials were conducted. Prompts within the app were used to instruct participants through the comfortable gait speed portion of the test; for the fast gait speed portion of the test, researchers read the same instructions but asked the participants to "walk as fast as you can without running" instead of asking them to walk at their usual speed.

EMG and Handgrip Dynamometry

During handgrip testing with ADinstruments equipment, a bipolar sEMG sensor was placed over the belly of the right first dorsal interosseous (FDI) and flexor carpi radialis (FCR) muscles, and a ground electrode was placed over the olecranon process of the right arm. Prior to placement of each sensor, the location of the aforementioned muscle bellies were determined through measurement between landmarks, as well as manual muscle testing techniques, and marked for accuracy of electrode placement; the skin was then shaved to remove any surface-level particles that could interfere with current conductance, and cleansed with rubbing alcohol. EMG sensors were attached to the surface of the skin via adhesive tape.

Handgrip testing for rate of force development was performed through the use of the ADinstruments Grip Force Transducer dynamometer. Participants sat with a neutral posture and the dynamometer in their dominant hand and were then asked to squeeze the dynamometer as quickly as they could with as much strength as possible three times, with the first time serving as a trial period to eliminate a lack of familiarization with the tool from affecting their scores. There was one minute of rest in between each run to allow participants to recover fully. The mean score between the two later runs were utilized for data collection[3]. This procedure was performed bilaterally to determine the magnitude of force and muscle activation during handgrip testing.

Statistical Analyses

The NIH Toolbox software automatically takes the fastest of the two test trials when analyzing gait speed, so this data set was used for our calculations. Data is presented in total time to complete the 4 meter course and was individually converted to gait speed in meters per second through spreadsheet software. Rate of EMG rise was measured over a 200 ms time span and was presented in the muscle activity at 0ms, 30ms, 50ms, and 75ms time intervals. The 75 ms time interval was chosen for data analysis.

A Pearson correlation coefficient test was performed to determine the correlation between gait speed and rate of EMG rise of the flexor carpi radialis muscle. Significance was calculated through a two tailed correlation test. An alpha level of 0.01 was used to determine statistical significance for all procedures. SPSS software (version 23.0, IBM Corporation, Armonk, NY, USA) was used for all statistical analyses. A linear scatterplot was created to display the relationship between the two variables.

RESULTS

The participants in this study had a mean ± SD comfortable gait speed of 1.3013 ± 0.34 m/s. This average gait speed is only slightly above the expected average of 1.18 m/s and 1.11 m/s for men and women in the 18-29 years age group respectively[5]. The average rate of electromyographic rise of the flexor carpi radialis muscle (RER_{FCR}) was 281.51 ±146.57 mV/s. Analysis was done using a two-tailed correlation test which calculated a Pearson correlation coefficient of 0.686. This value suggests a moderate, positive correlation between gait speed and RER_{FCR} ruling out the null hypothesis.

Previous research has demonstrated a correlation between gait speed and height with shorter participants demonstrating slower gait speeds[6]. However, this study showed a negligible correlation between these two variables with a Pearson correlation coefficient of 0.066. Similarly, age has also been shown to influence gait speed with a decrease noted as individuals age[6]. In this study, only a low positive correlation was seen between age and gait speed with a Pearson correlation coefficient of 0.483.

Despite the small sample size resulting in a less ideal overall statistical power, the p-value was calculated to be 0.003 indicating that the correlation between gait speed and RER_{FCR} is statistically significant ($p<0.01$). The coefficient of determination ($r^2 = 0.471$) indicates that 47% of the data fit the linear regression model. Some inaccuracies may be due to individuals with a slower gait speed, such as participant 002 with a gait speed of 2.38 m/s as compared to the average gait speed of 1.30 m/s. (Figure 1)

DISCUSSION

This study contributes to the current body of literature regarding predictors of gait speed and subsequent fall risk. The number of participants (n=16) limited this study's statistical power, and in spite of this, the data analysis indicates that handgrip RER measured at the FCR from 0 to 75 ms is significantly positively correlated with comfortable gait speed in college-aged adults. The results from examining this early period of muscle contraction and associated electrical activity as measured by surface EMG electrodes not only confirms our hypothesis that there is a relationship between the two variables, but shows that motor neuron discharge rate plays a role in gait speed.

It is widely known that when demands are imposed on muscles, they specifically adapt to the stimuli, altering or honing their function to a certain extent. Now that we know that there is a direct relationship between muscle activity in the first 75 ms of muscle contraction and comfortable gait speed, which can be used to predict a person's risk of falling, how or what do we train to improve this factor to lessen this risk? Current research does not indicate that neural factors involved in muscle contraction can be altered through training interventions to this end, but what about the muscular factors?

Our study opens a door to investigating whether muscular power is another key component of gait speed. We see that an increased rate of muscle activity, specifically of the FCR, can be used to predict performance on comfortable gait speed tasks and assess fall risk, but we cannot assume that there is a concurrent increase in rate of force production or power. However, it is possible that due to the close relationship between RER and RFD[12], clinicians adding power training exercises to their plans of care for patients with slow gait speed or high risk of falls may be fitting. These plyometric exercises could be done in the upper extremity as well as the lower extremity as this study shows a link between the rate of EMG rise in the upper extremity and lower extremity function as assessed by comfortable gait speed.

Future research with a larger sample size is warranted to enhance the results of this study and aid in the investigation of therapeutic interventions to decrease fall risk via gait speed and power training. Addressing the role of rate of force development as it relates to gait speed may further this investigation. Additionally, examining the strength of correlations between maximal strength and gait speed versus maximal power and gait speed may also provide valuable information for developing effective interventions for those at risk for falls. For clinicians who seek to improve their patients' fall risk, is it more beneficial to implement training protocols that target muscular strength, or muscular power? Is it more important simply to be strong, or to be able to employ strength over a short period of time? We hope that other researchers will look into questions like these to help clinicians effectively tailor programs for their patients with high fall risk.

REFERENCES

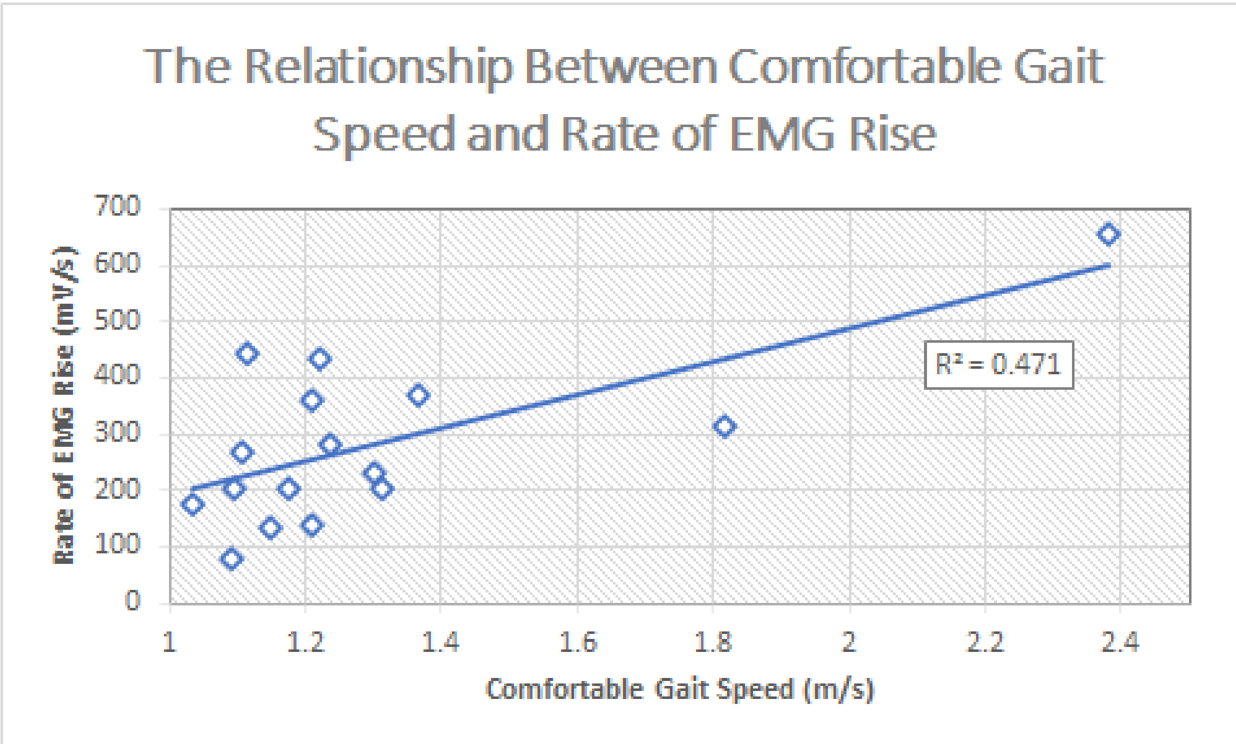
1. Aagaard P, Simonsen EB, Andersen JL, Magnusson P, Dyhre-Poulsen P. Increased rate of force development and neural drive of human skeletal muscle following resistance training. J Appl Physiol (1985). 2002;93(4):1318-1326. doi:10.1152/japplphysiol.00283.2002
2. Abellan van Kan, G., Rolland, Y., Andrieu, S., Bauer, J., Beauchet, O., Bonnefoy, M., . . . Vellas, B. (2009). Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) Task Force. J Nutr Health Aging, 13(10), 881-889. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/19924348.

3. Alonso AC, Ribeiro SM, Luna NMS, et al. Association between handgrip strength, balance, and knee flexion/extension strength in older adults. PLoS One. 2018;13(6):e0198185. Published 2018 Jun 1. doi:10.1371/journal.pone.0198185
4. Artaud F, Singh-Manoux A, Dugravot A, Tzourio C, Elbaz A. Decline in Fast Gait Speed as a Predictor of Disability in Older Adults. J Am Geriatr Soc. 2015 Jun;63(6):1129-36. doi: 10.1111/jgs.13442. Epub 2015 Jun 11. PMID: 26096387.
5. Bohannon RW, Wang YC. Four-Meter Gait Speed: Normative Values and Reliability Determined for Adults Participating in the NIH Toolbox Study. Arch Phys Med Rehabil. 2019;100(3):509-513. doi:10.1016/j.apmr.2018.06.031
6. Bohannon RW. Comfortable and maximum walking speed of adults aged 20-79 years: reference values and determinants. Age Ageing. 1997;26(1):15-19. doi:10.1093/ageing/26.1.15
7. Demnitz N, Esser P, Dawes H, Valkanova V, Johansen-Berg H, Ebmeier KP, Sexton C. A systematic review and meta-analysis of cross-sectional studies examining the relationship between mobility and cognition in healthy older adults. Gait Posture. 2016;50:164–74.
8. Josephson MD, Rose WC, Knight CA. Evidence of bilinearity in the relationship between rate of neuromuscular excitation and rate of force development. J Electromyogr Kinesiol. 2019;49:102355. doi:10.1016/j.jelekin.2019.102355
9. Lee A. Preventing Falls in the Geriatric Population. The Permanente Journal. February 2013:37-39. doi:10.7812/tpp/12-119.
10. Liu MA, DuMontier C, Murillo A, Hshieh TT, Bean JF, Soiffer RJ, Stone RM, Abel GA, Driver JA. Gait speed, grip strength, and clinical outcomes in older patients with hematologic malignancies. Blood. 2019 Jul 25;134(4):374-382. doi: 10.1182/blood.2019000758. Epub 2019 Jun 5. PMID: 31167800; PMCID: PMC6659254.
11. Puthoff ML, Nielsen DH. Relationships among impairments in lower-extremity strength and power, functional limitations, and disability in older adults. Phys Ther. 2007; 87:1334–1347.

12. Varesco G, Espeit L, Feasson L, Lapole T, Rozand V. Rate of force development and rapid muscle activation characteristics of knee extensors in very old men. Experimental Gerontology. 2019;124:110640. doi:10.1016/j.exger.2019.110640
13. Winters JD, Rudolph KS. Quadriceps rate of force development affects gait and function in people with knee osteoarthritis. Eur J Appl Physiol. 2014;114(2):273-284. doi:10.1007/s00421-013-2759-8

FIGURES AND TABLES

Figure 1. A visual representation of the relationship between comfortable gait speed and rate of electromyography rise in the flexor carpi radialis muscle.



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Participant ID	Age (years)	Sex (M/F)	Height (cm)	Weight (lbs)	Ethnicity	Amount of Exercise per Week (min)
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002	29	F	64.5	136	Asian or Pacific Islander	540
003	32	M	72	194	White	180
004	20	F	67.75	126	Hispanic	240
005	20	F	65.75	126	White	60
006	27	M	72.5	197	Hispanic	150
007	23	F	67	224.4	White	120
008	22	M	66.75	159	Hispanic	300
009	19	F	67	128	Asian or Pacific Islander	90
010	18	M	68.5	148	White	1,320
011	19	F	65.25	128	White	270
013	21	F	61.75	127	Asian or Pacific Islander	360
014	24	M	60.5	188	White	240
015	22	F	70	168	Black	600
016	27	F	66.2	143	White	150
017	25	M	63.6	180	Asian or Pacific Islander	240

Addendum 1a. Front Side of Telephone Screening Form (Researcher Script)

Telephone Screen Screener Initials: ____ Date: ___/___/_____

Name: ______________________________ Phone Number: ____-____-_____ Reminder Type: Call / Email / Text / Declined

I. Greeting

"Good morning/afternoon/evening. This is ***Say your name*** from UCF Physical Therapy. I'm calling because you've expressed interest in participating in our capstone research study. Do you have a few minutes to talk about our study?" ***Pause for response***

- ***If unable to speak at that moment:*** "That's okay! When would be a better time for us to chat?" ***Schedule screening***
- ***If able to chat:*** "Great! So, we are conducting this study to see how reaction time correlates with two factors: rate that a muscle can produce force as well as processing speed. During the study, you will be asked to answer some questions about your medical history, perform a strength, balance, and gait assessment, and perform a few cognitive tests on an iPad. We will also use a simple, non-invasive magnetic device to produce a muscle contraction in your hand. Is it okay if I ask you a few questions to see if you're eligible to participate?" ***Flip over for list of screening questions***

III. Results Interpretation

- ***Eligible*:** "Thank you for answering those questions. It looks like you're a good match for this study, and if you're interested, we would like to schedule a time for you to come into the lab. All information obtained will be used only for the research study so it will remain confidential. Participation in this study is completely voluntary, and there will be no consequences to you if you decide to withdraw at any point. I'd also like to remind you that this study will require a commitment of 1.5 to 2 hours of your time. Are you still interested in scheduling an appointment to participate?"
  - ***Uninterested:*** "That's okay. Well, thank you for taking the time to chat with me about our study. Have a nice day/afternoon/evening."
  - ***Interested:*** "Great, thank you!" ***Schedule appointment*** "Okay, you're penciled in! Do you have the address for the lab?" ***Innovative Mobility Initiative (IMOVE) Lab located at 12354 Research Parkway, Suite 224, Orlando, Florida, 32826*** "There are some things that we ask our participants to keep in mind in preparation for their appointment.

  So, before your appointment, please:

  1. Bring or wear shorts and a loose-fitting top.
  2. Do not wear any jewelry to your appointment.
  3. Bring your reading glasses with you if needed.
  4. Do not ingest caffeine within 4 hours of your appointment time.
  5. Do not consume alcohol within 24 hours of your appointment time.

  We know it's a lot to remember, so we usually do a day-before reminder; how would you like us to remind you: call, email, or text?" ***Mark option in header*** "Okay, so we will [call/email/text] you the day before your appointment. Do you have any questions?" ***Answer any questions*** "Well, thank you for your time! We will see you on [date] at [time]."
- ***If concerned about response(s):*** "Thank you for answering those questions. We want to make sure that you're as safe as possible, so we're going to confer with our study's physician about your responses, and we will call you again after we do so. Is it okay if we call you back at this number?" ***Pause for response*** "Is there a particular time of day that works best for you to receive a call?" ***Pause for response*** "Okay, great. So, we will contact you once we hear back from the study physician. Do you have any questions for us?" ***Answer any questions*** "Well, thank you for your time! Have a great day/afternoon/evening."
- ***Not eligible:*** "Thank you for taking the time to answer those questions. Unfortunately, due to ***List exclusion criteria***, you are not eligible to participate in this study. Again, thank you so much for taking the time to speak with us. I hope you have a great day/afternoon/evening."

Addendum 1b. Back side of Telephone Screening Form (Participant Responses)

Telephone Screen   Screener Initials: ____ Date: ___/___/_____

Name: ______________________________ Phone Number: ____-____-_____ Reminder Type: Call / Email / Text / Declined

II.	SCREENING QUESTION	NO	YES	COMMENTS
1.	Has a physician ever informed you that you have a neuromuscular disease, such as Parkinson's, multiple sclerosis (MS), or amyotrophic lateral sclerosis (ALS)?			
2.	Have you ever had trouble using or controlling your muscles?			
3.	Do you have a personal history of cancer, stroke, or heart attack?			
4.	Are you currently taking any prescription medications? • EXCLUDE PARTICIPANT if meds include: muscle relaxants, benzodiazepines			
5.	Are you able to walk at least 20 feet on your own without an assistive device?			
6.	Do you have epilepsy or have you ever had a convulsion or a seizure?			
7.	Have you ever had a fainting spell?			
8.	Have you ever had a head trauma that was diagnosed as a concussion or was associated with a loss of consciousness?			
9.	Do you have any hearing problems or ringing in your ears?			
10.	Do you have cochlear implants?			
11.	Do you have metal in the brain, skull, or elsewhere in the body? • If yes, please specify where and the type of metal.			
12.	Are you allergic to rubbing alcohol?			
13.	Do you have a pacemaker or intracardiac lines?			
14.	Do you have a medication infusion device or an implanted neurotransmitter?			
15.	Have you ever undergone TMS in the past? • If yes, were there any problems?			
16.	Have you ever undergone MRI in the past? • If yes, were there any problems?			
17.	Do you have means of transportation to get to and from the laboratory?			
18.	Are there any other health-related conditions that you currently suffer from that you believe would prohibit you from performing physical performance testing or that you think we should know about, such as any musculoskeletal injury within the past year? • If yes, do they think that it will impact their ability to perform walking or maximal gripping activities?			

Flip over for results interpretation scripts