Title: Transfemoral Socket Design and Muscle Function

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Hip Muscle Function in Lower Limb Prosthesis Users

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LIST OF ABBREVIATIONS

COI	Conflict of Interest
EMG	Electromyography
IRB	Institutional Review Board
PI	Principal Investigator
PLUS-M	Prosthetic Limb Users Survey – Mobility
PROMIS	Patient-Reported Outcomes Measurement Information System
REDCap	Research Electronic Data Capture
SENIAM	Surface Electromyography for the Non-Invasive Assessment of Muscles

1.0 Project Summary/Abstract

The **objective** of this research project is to evaluate hip muscle function among lower limb prosthesis users, its contribution to balance and mobility, and the effect of prosthetic socket design on amputated limb hip muscle strength and endurance. Traditional socket designs can provide pelvic support that interferes with hip motion. They may also reduce the effort required from amputated limb hip muscles to stabilize the hip and amputated limb, risking further loss of muscle mass and strength beyond that due to amputation. Long-standing use of sockets with pelvic support may therefore intensify amputated limb muscle loss and weakness, leading to challenges with walking and balance, increasing the effort required to walk, and contributing to degenerative changes in the hips and knees.

2.0 Background/Scientific Rationale

Residual limb hip muscle weakness is a pronounced, consequential, and modifiable deficit among prosthesis users that is not adequately understood. After amputation residual limb hip muscles undergo structural changes, such as atrophy[1,2,3] and fatty infiltration[4,3], causing pronounced muscle weakness[2,5-7]. These changes are not observed with the same frequency or magnitude in the intact leg[5], suggesting they are due to amputation[13] and/or socket design[9] rather than general deconditioning[5]. Assessments of residual limb strength have, to date, however been limited to non-fatiguing conditions, and measures of maximum voluntary strength[2,5,6]. Important functional aspects of strength including the rate of force development, which is essential to balance[10-11], and muscular endurance, which is crucial to mobility[12,31] and strenuous tasks like load carriage[12], have been overlooked. Additionally, a number of major residual limb hip muscles and relevant covariates (e.g., etiology) remain untested. As a result, we do not have a full understanding of the force generating capacity of residual limb hip muscles in transfemoral prosthesis users that is required to assess the effect of socket design on residual limb hip muscle function. To address this gap a comprehensive evaluation of residual limb hip muscle strength and endurance is needed.

Preliminary evidence suggests residual limb hip muscle weakness is a consequential deficit among transfemoral prosthesis users. Muscle weakness has been associated with gait abnormalities[1,13], secondary degenerative disorders (e.g., joint degeneration)[14], increased metabolic cost of gait[15,16], as well as reduced mobility[17,18] and balance confidence[19]. Causal links however between residual limb hip muscle function and balance or mobility remain poorly understood among transfemoral prosthesis users[21]. Preliminary statistical modeling of causal relationships between residual limb hip muscle function and walking and balance performance is needed to address this gap.

Fortunately, residual limb hip muscle weakness appears to be a modifiable, and thus a treatable deficit in transfemoral prosthesis users. Gains in residual limb hip muscle strength have been observed in lower limb prosthesis users after only moderate strength training (8-12 weeks; 2/week)[15,19,21]. Whether socket design has a similar modifying effect on residual limb hip muscle strength is unknown, but presents an appealing opportunity. The prospect of increasing residual limb hip muscle strength and endurance simply by walking with a different socket design is attractive because it could be accomplished in a patient's own home, community, and workplace, without additional equipment (i.e., environment and activity specific strength training). Our prior results and anecdotal reports support a study to quantify changes in residual limb hip muscle function in lower limb prosthesis users wearing different sockets.

3.0 Objectives/Aims

The objective of this study is to assess residual limb hip muscle function in lower limb prosthesis users, understand its role in balance and mobility, and the effect of socket design on residual limb hip muscle function. Our central hypothesis is that the residual limb is weaker than the intact limb as well as controls, and that socket design alters hip muscle function. To address this objective and central hypothesis, we will assess the following specific aims:

Aim 1: Evaluate hip muscle function and its contribution to balance and mobility among unilateral lower limb prosthesis users. We hypothesize that: i) the strength and endurance of hip muscles on the residual limb will be lower than on the intact limb, and of age- and sex-matched able-bodied persons, and ii) muscular strength and endurance will not differ between the intact limb and age- and sex-matched able-bodied persons. To test these hypotheses hip muscle strength and endurance will be measured using a motor-driven dynamometer. Lower peak torque and rates of torque development will be taken as evidence of reduced strength, while a larger decrease in average work at the end of an isokinetic fatigue protocol will be taken as evidence of reduced endurance. Secondarily, we will also collect balance and mobility outcomes data (e.g., Four Square Step Test, PLUS-M, step counts, and fall history), and use regression methods to explore the contributions of hip muscle strength and endurance to balance and mobility in lower limb prosthesis users.

Aim 2: Test whether socket design alters hip muscle function among lower limb prosthesis users. We hypothesize that walking with different socket designs will: i) require different residual limb hip muscle activity, as evidenced by greater peak muscle activity, as well as altered onset and offset times, and ii) result in short- and long-term gains in residual limb hip muscle strength and endurance, as evidenced by an increase in average peak torque, rate of torque development, and resistance to fatigue. To test these hypotheses electromyographic signals will be recorded from hip muscles on the residual limb of unilateral lower limb prosthesis users walking at a range of speeds. Hip muscle strength and endurance will be measured using a motor-driven dynamometer. Assessments will be made at baseline in established wearers of an ischial containment socket, and then again at eight and 42-weeks after being fit with a sub-ischial socket. Step count activity data will be collected to determine the extent to which gains in residual limb hip muscle strength and endurance are due to changes in hip muscle activation versus an increase in physical activity.

4.0 Eligibility

The target population for the proposed study is adult unilateral lower limb prosthesis users whose amputation is due to traumatic, dysvascular, or oncologic reasons. We will not exclude participants based on age, race, sex, or ethnicity. In an effort to recruit and include under-represented minorities will we monitor participant demographics during the study and adjust our efforts as necessary to improve the inclusion of under-represented groups.

We will recruit lower limb prosthesis users in Chicago from Scheck and Siress Prosthetics and Orthotics. Scheck and Siress have over a dozen clinics in the Chicagoland area. Their offices regularly treat more than 2000 lower limb prosthesis users a year. Clinicians at Scheck and Siress will only participate in passive recruitment, sharing information about current research participation opportunities with patients. We may recruit from other clinics in the Chicagoland area if recruitment proves to be challenging.

Participant eligibility will be evaluated and determined by the investigators or research staff using specific inclusion and exclusion criteria via in-person or phone interviews. In person interview will occur in any of three locations:

1. Disability, Health, and Social Policy Building, Room 198 1640 W. Roosevelt Road, Chicago IL, 60608
2. Applied Health Science Building, 1919 W. Taylor Street, 646; Chicago, IL 60612

4.1 Inclusion Criteria

Inclusion criteria for lower limb prosthesis users will be: 1) worn prosthesis for ≥ 2 years, 2) able to walk short distances (10 meters), 3) ability to read, write, and speak English, and for Aim 2 only, ≥ 2 years using a liner-based suspension, and a residual limb length ≥ 5”. Inclusion criteria for unimpaired controls will be: 1) ability to read, write, and speak English, 2) between the ages of 18-85 years of age, and 3) able to walk short distances (10 meters).

4.2 Exclusion Criteria

Exclusion criteria will be: 1) amputation of a second leg, 2) contralateral complications (e.g., hip replacement), or 3) other major neuromusculoskeletal or cardiovascular conditions (e.g., heart failure). Age- and sex-matched able-bodied persons will be recruited from the community for Aim 1 with non-amputation related criteria applicable (e.g., major neuromusculoskeletal or cardiovascular conditions).

4.3 Excluded or Vulnerable Populations

Subjects younger than 18 and older than 85 years of age will be excluded, as their inclusion would introduce confounding factors of sensorimotor changes due to motor development and aging.

Subjects for whom English is a second language will also be excluded because there are extensive verbal instructions that must be provided to the participants. Translation services are not readily available to assist laboratory personnel. Participants will also be expected to provide information via self-report survey instruments that have not been translated and/or validated in other languages.

Individuals with bilateral lower limb loss and any upper extremity limb loss will be excluded, as their biomechanics are not comparable to individuals with unilateral lower limb loss.

5.0 Subject Enrollment

Lower limb prosthesis users will be recruited from prosthetics clinics in Chicago via flyers or information about the study provided to them by clinic staff during clinic visits. Age- and sex-matched able-bodied persons will be recruited from the community via flyers placed on the UIC campus.

To minimize coercion or undue influence over the patient population of interest, lower limb prosthesis users, it will be communicated to them that their clinical care does not depend in any way on whether they elect to participate or not in this research study.

If an individual shows interest in participation in the study, we will obtain general health information from them to confirm that they are eligible for study participation. General health information will include age, weight, and self-reported medical history, including if they have any vision impairments, balance impairments, cognitive impairments, progressive neurological conditions, or any other major motor or sensory dysfunction or medical condition. This screening process could talk place via a telephone interview or in person. Regardless of the method, screening will be done in a private room to protect participant's confidentiality. After participants review and sign consent forms on the day of the assessment, we will obtain more detailed health information during an interview using several surveys and questionnaires.

Any data that is collected from participants who are not eligible or interested in participating in the study will be deleted from our records. Electronic data will be permanently erased from the stand alone PC on which it is collected. Any hard copies will be shredded.

6.0 Study Design and Procedures

Consented individuals will participate in 1 or 3 test sessions. Each session will require approximately 3 hour. For Aim 1, we will conduct a cross-sectional study to evaluate residual and intact limb hip muscle function in lower limb prosthesis users compared to able-bodied persons. All participants will be administered characterization measures, balance and mobility tests, as well as a series of procedures to evaluate hip muscle strength, endurance, and coordination. This will require a single 3-hour test session. Able-bodied controls and lower limb prosthesis users will perform the same activities in Aim 1.

For Aim 2, we will conduct a pilot within-subjects study to assess if walking with a different socket alters residual limb hip muscle function. In Aim 2, a sub-set of lower limb prosthesis users from Aim 1 will walk with a different socket. These participants will be selected on the basis of meeting the inclusion and exclusion criteria specified above for Aim 2. The same measures, tests, and procedures from Aim 1 will be administered in Aim 2 at two time points, eight and 42-weeks after baseline testing. Outcomes at these two time points will be compared to baseline (Aim 1) to evaluate differences in hip muscle function associated with walking in a different socket. Three total test visits will be required of participants in Aim 2.

The tasks listed below will be performed at each visit.

Characterization Measures: Sociodemographic, health, falls history (all subjects), and prosthetic-related information (prosthesis users only) will be collected using psychometrically robust self-report outcomes to characterize study participants. This will include age, general health (PROMIS 29), residual limb length, cause and time since amputation, mobility (Prosthetic Limb Users Survey-Mobility), socket comfort (Socket Comfort Score), and balance confidence (Activities-specific Balance Confidence Scale). Falls history will be obtained by asking participants "*in the past year have you inadvertently lost your balance and landed on the ground or lower level?*". Amputation surgical techniques (e.g., muscle fixation) may vary across participants, and confound assessments of residual limb hip muscle function. In an effort to obtain this data we will create a permission form to be signed by the participant and sent, along with a short survey, to their surgeon requesting basic information about the amputation procedure (e.g., myoplasty versus myodesis).

Hip Muscle Strength and Endurance: Hip flexor, extensor, adductor and abductor muscle strength and endurance will be measured in lower limb prosthesis users and able-bodied persons using a motor-driven isokinetic dynamometer (Biodex System 4 Pro, NY). Participants will be secured in standardized positions that maximize stability and minimize compensatory movements, providing the most valid and reliable measurements (i.e., side-lying for adduction/abduction, supine for flexion/extension). The axis of the dynamometer will be aligned to the hip joint, and the arm of the dynamometer will be adjusted to the greatest length that is comfortable and allows for firm attachment of custom-made shells to the test limb. The mass of the tested limb will be measured in a relaxed position by the dynamometer to correct for gravity. Three submaximal repetitions will be performed in each test position to familiarize participants with the test procedure. Fifteen consecutive maximal voluntary isometric contractions will then be performed in each test position. Isometric concentric testing was chosen because of its validity and reliability, and its relationship to walking capacity. Mandatory 5-minute rest periods will be enforced between testing in each position. Muscular strength will be assessed via average peak torque (i.e., highest torque) and rate of torque development (i.e., slope of the torque/time curve from onset to peak) across the first three repetitions. Torque onset will be defined as the instant torque exceeds 2% of peak torque. Lower values will be taken as evidence of reduced muscular strength. Muscular endurance will be assessed via a fatigue index, calculated as a percentage of the difference between total work performed during the first and last 5 repetitions divided by total work over the first 5 repetitions. A higher fatigue index will be taken as evidence of reduced muscular endurance. All values will be normalized to body weight, and the order of test positions will be randomized.

Hip Muscle Activity: Surface electromyography (EMG) data will be recorded at 1200Hz (Motion Labs, Baton Rouge, LA) from six muscles (adductor magnus, rectus femoris, tensor fascia latae, gluteus medius, biceps femoris long head, and gluteus maximus) on the residual limb of prosthesis users walking at preferred, slow (-25%), and fast (-25%) speeds on a force-sensing treadmill (Treadmetrix, Salt Lake City, UT). Speeds will be maintained across test sessions (baseline, 8-, and 42-weeks). Ground reaction forces will be recorded simultaneously at 1200Hz to identify gait cycle events. Neonatal electrodes, placed according to the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) standards, will be

used to accommodate the collection of in-socket EMG signals. Raw EMG signals will be: i) band-passed filtered (10-500Hz) to remove non-muscle frequencies, ii) high-pass filtered (50Hz) to remove motion artifact, iii) notch-filtered (59.5-60.5Hz) to remove ambient power line noise, iv) amplitude normalized to the peak of the subject's ensemble average during fast walking on visit 1, and v) time normalized to 100% gait cycle (i.e., initial contact to initial contact). Activity of residual limb hip muscles will be characterized by onset and offset times, as well as the integrated area and peak activity. Onset and offset times will be identified from processed EMG signals using a Teager-Kaiser energy operator signal-conditioning algorithm, and referenced to initial contact. This procedure detects EMG burst boundaries with greater accuracy than other methods. The integrated area and peak activity of EMG bursts will be calculated by applying trapezoidal integration and thresholding techniques to linear EMG envelopes generated from full wave rectification and low-pass filtering (10Hz cut-off) of processed EMG signals. Muscle activity metrics will be averaged over a minimum of 10 strides per participant. EMG processing and analyses will be performed using custom Matlab™ (MathWorks Inc., Natick, MA) routines.

Balance and Mobility Tests: To assess balance and mobility, prosthesis users will be administered six standardized and psychometrically robust performance-based clinical tests: Four Square Step Test (dynamic balance), One Leg Stance Test (static balance), 10-Meter Walk Test (walking speed), 2-Minute Walk Test (walking endurance), 5-Times Sit to Stand (muscular strength), 30-second Sit to Stand (muscular endurance), or Functional Reach Test (postural balance). Tests will be administered in a randomized order, and according to the developer's instructions. Mandatory 5-minute rest periods will be enforced between each test.

Step Count Activity: To assess physical activity, lower limb prosthesis users will wear a StepWatch4 activity monitor (Modus Health, Edmonds, WA) for three 2-week periods. First, immediately after baseline testing, and then for two weeks prior to both the eight and 42-week tests. StepWatch has a step count accuracy above 98%. Activity bouts, or periods of time in which steps occur in successive 10-second intervals, will be derived from step count data. Physical activity will be quantified by its volume (i.e., mean number of steps per day), frequency (i.e., mean number of activity bouts per day), and duration (i.e., mean length of activity bouts per day). Higher values will be taken as evidence of greater physical activity.

Video images: During the study, video records will be collected of the assessments. Video files will be stored on a computer as a visual record of the events that occur during the trials and may be kept indefinitely for analysis by the researchers in a secured and locked location. The video will only be accessible by research personnel, unless the participant gives permission otherwise on the consent form.

7.0 Expected Risks/Benefits

Foreseeable, potential risks for prosthesis users and able-bodied controls participating in this study include: a) fatigue resulting from long periods of standing or walking, b) injury from mechanical failure of the equipment (e.g., treadmill, motorized dynamometer), c) falling during administration of the study protocol, d) electrical shock associated with recordings of

electromyograms (EMG), e) irritation to the skin from medical grade tape used to attach sensors to the body, or f) embarrassment. The risk associated with these events is expected to be low. We have attempted to reduce known potential risks. We do not know of alternative procedures that can reduce these risks and provide the same information. The safety precautions associated with the potential risks are as follows:

a) Loss of balance and falls: All study personnel will undergo falls training led by the PI. This training will familiarize them with appropriate spotting techniques to catch a participant if they begin to fall.

b) Fatigue: The test sessions may last up 3 hours, however, only 90 minutes are dedicated to study procedures. This duration may nonetheless be fatiguing to some participants. The majority of the time is devoted to participant preparation and instrumentation, a large part of which is done while the participant is either sitting or lying down. We will enforce sitting breaks of at least 5 minutes every 20 minutes of experimentation. The breaks will only end with the participant's consent and participants will be continually monitored during testing by the evaluator and trained assistants for fatigue and instability.

c) Mechanical injury: The treadmill and motorized dynamometer are physically limited by the motor torque and cannot deliver excessively large, injury-causing perturbations. They are equipped with limit switches that shut down power if they reach near the end range of their capabilities. Software limits further limit uncontrollable movements of the treadmill and dynamometer. There is an emergency stop button next to the experimenter and on the treadmill as well as the dynamometer for participants. Additionally, all equipment will be inspected for safety as part of the set up routine for each data collection session.

d) Electrical shock: The risk of electrical shock is extremely low and limited to non-injurious levels of current and voltage. Our electromyography equipment is a telemetered unit powered by a standard 9-volt battery. Therefore if a malfunction were to occur, any electrical shock produced would be extremely mild. Our equipment is available commercially (Motion Lab Systems) and no participants have experienced any electric shock or tingling sensations due to current flow.

e) Skin irritation: Some participants are sensitive to the adhesive used in medical grade tape. This can result in temporary irritation such as redness or itchiness in areas where tape has contacted the skin. We will ask participants if they have known tape sensitivity before the experiment begins. The supply of tapes and adhesives we use are hypoallergenic medical grade that are commonly used in hospitals. In the PI's experience in and around the testing of hundreds of human participants with similar supplies, only one case of tape allergy has occurred. This one incident left no permanent injury to the participant.

f) Discomfort/embarrassment: To reduce potential discomfort or embarrassment in answering health related questions all questionnaires will be completed in a private room. If participants do not want to answer particular questions they do not have to. To reduce embarrassment of being videotaped all recordings will be taken from behind. Faces will not be recorded. Any identifiable marks will be blurred if videos are ever used

in a presentation. Video recording is optional. To minimize any potential embarrassment due to loss of confidentiality all records of participation that included information about participants will be coded. Names and unique subject IDs do not appear on the same documents. The data from this study cannot be traced directly back to participants. Additionally, all documents from this research will be kept in a locked file cabinet by the study team. We are the only ones with access to these documents.

We do not anticipate that participants will receive any direct benefit from participating in the study. The study is not being conducted to improve their health condition. It is hoped that knowledge gained from this research may benefit other lower limb prosthesis users in the future by providing an approach to increase and/or prevent the loss of residual limb hip muscle strength.

8.0 Data Collection and Management Procedures

Muscle activity data, as well as isometric strength data will be collected on a stand-alone desktop computer and stored electronically on that PC as well as a backup hard drive. Access to this data on the PC and the external hard drive will be protected via a password that only the PI and his students will have access to. Both the PC and external hard drive are located in our lab, which is locked.

Data collected using performance-based balance and mobility tests will be recorded on paper data collection forms. Collected data will be stored in subject-specific folders, located in a locked filing cabinet (separate from consent form cabinet). Keys for this cabinet will be kept in a lockbox with a 4-digit passcode that only the PI and his students will know.

Survey responses collected during experiments will be entered and stored in a secured REDCap database. REDCap will only be assessable to study personnel including the PI, Co-I, and other research staff via password protection. This ensures that de-identified data will be secure yet available to all investigators involved in the study.

A master code sheet linking subject names to study ID # will be kept in the PI's or site PI's offices in a locked cabinet. This location is separate from where the data is collected and stored. Only the PI or site PI will have access to this master list. The master list is necessary for the multiple visit portion of the study. When subjects return for their 2nd and 3rd visit we will have to assign them the same ID# as in previous visits.

9.0 Data Analysis

Data will initially be processed in the lab on the stand-alone PC and then backed up to the external hard drive. The PI and his students will perform additional analyses on computers in their office space that are password protected. Data analysis may include the use of such computer programs as Matlab, SPSS, and Excel.

At no point will any data on the lab stand-alone PC, the PI's computer, or those of his students contain any private health information or data that could be linked to specific subjects via personnel identifiers.

10.0 Quality Control and Quality Assurance

After every assessment, the PI and/or one of his students will review that all inclusion and exclusion criteria for screening were met. They will also review that all data was collected in a manner that is consistent with what is outlined in the protocol and consent form. Any departure from the protocol or failure to meet inclusion/exclusion criteria will be reported to the IRB and the data will be deleted.

Collected data will be regularly entered into entered into REDCap and reviewed by the site PIs. This will provide regular review of the data quality.

11.0 Data and Safety Monitoring

To ensure the safety of subjects and keep personal information private the following procedures will be followed. In the event of an injury or adverse event we will call 911 if necessary, and report any adverse event to the IRB in a timely manner (within 3 business days). Subjects requesting medical treatment will be directed to the appropriate source of treatment. These adverse events could be physical injury or a breach in confidentiality. We will maintain a safety log of adverse events (falls, skin irritation, breach of confidentiality etc) for each session that is kept in a locked drawer in the lab. A brief summary of the experiment, whether any adverse events occurred, when they were reported, and what actions will be taken to prevent them in the future will be recorded after. An example of this log is attached to this application ("Research Safety Log").

12.0 Statistical Considerations

Descriptive statistics: Measures of central tendency and variation will be used to describe participant characteristics, and all study variables (e.g., balance and mobility tests, muscle strength). Normality, homogeneity of variance, and multicollinearity will be evaluated using the Shapiro-Wilk test, Levene's test, and, Pearson's r ($r<.90$) respectively. If assumptions are met data will be analyzed with parametric tests, otherwise non-parametric tests will be used. Statistical analyses will be performed using SPSS 25 (Chicago, IL).

Aim 1: A 2-way mixed-MANCOVA (multiple analysis of covariance), or non-parametric equivalent, will be used to test for statistically significant differences in strength and endurance between legs (prosthetic, intact, and control) as well as across muscle groups while controlling for potential covariates (e.g., residual limb length, etiology). Multiple linear regression will be used to determine how much variation (i.e., difference) in balance and mobility outcomes (e.g., Four Square Step Test; physical activity) among transfemoral prosthesis users can be explained by differences in hip muscle strength and endurance.

Aim 2: As a pilot study, descriptive analyses including measures of central tendency (mean) and dispersion (95% confidence intervals), along with effect sizes (e.g., Cohen's d, common

language effect size), will be used to evaluate changes in residual limb hip muscle activity, strength, between test sessions while controlling for covariates. Correlation analyses will be used to determine if any observed changes in hip muscle strength can be attributed to changes in hip muscle activity (i.e., EMG) or physical activity (i.e., step count).

Power Analysis: Choosing a power of 0.80 and a type I error rate (α) of 0.05, pilot data from lower prosthesis users (n=2) and able-bodied persons (n=2) estimate that a sample of 20 people per group will be sufficient to identify differences ($p<0.05$) in hip muscle strength and endurance between the residual limb, intact limb, and able-bodied persons using a mixed analysis of variance (ANOVA) (Aim 1). As a pilot study, enrollment in Aim 2 will be limited to 10 unilateral lower limb prosthesis users.

13.0 Regulatory Requirements

13.1 Informed Consent

When participants arrive in the lab, they will meet study staff and review the informed consent form with him and/or other research personnel. The PI and/or other research personnel will review all of the key points in each section and allow the participant to read the consent form and ask any questions. Participants will participate in the experiment only after granting full informed consent. Consent capacity will be assessed by a discussion of the proposed research project. During the consent process, a series of questions can be asked to assess understanding of key issues. Such questions will relate to the purpose of the research and the foreseeable risks and anticipated benefits of study participation or understanding of the voluntary nature of research and the elements of consent, including the right to be informed about appropriate alternative procedures or courses of treatment that may be available.

All participants will be told that if they choose not to consent, at this time or anytime during the study, they will be allowed to stop and leave. They will also be told that by consenting at the start of the study they are not required to finish the study. They are free to end their participation at any time without having to give an explanation. They can then decide whether they want their data deleted or if it can still be included in our analyses. This will be documented in a revocation form. Participants will also be told that will still be compensated for their time spent in the study prior to terminating their participation.

During the consent process all participants will be given the opportunity to consent to having video taken during their experiment. They will be asked to check yes or no and initial beside their selection. Options for the use of the video will include reviewing the video to make sure all protocols were performed appropriately, as well as use in presentations at conferences. Participants will be told that their selection to consent to video will not affect their eligibility to participate in the current study.

Participants will also be asked if they would like to be entered into a participant pool and be called if future studies may be of interest. This participant pool will be separate from any collected data during the study. Participants will be informed that their decision of whether to agree to be added to a participant pool will not affect their eligibility to participate in the current study.

Prior to being delegated any informed consent responsibilities, all lab personnel will complete the institutional requisite IRB training, observe 2-3 consent processes, and then perform 2-3 consent processes with the PI or other study investigator present.

All informed consent documents will be stored in a locked file cabinet, in the lab that is also locked. All lab personnel will have lab keys (currently just PI, grad students in future). Keys to the file cabinet will be kept in a key lockbox, in the lab, that has a 4-digit numerical code that only the principal investigator and lab personnel will know.

13.2 Subject Confidentiality

Records will be coded by alphanumeric study ID numbers that are linked to participant's name, email and phone number via a master list. This master list will be kept in a separate office from data records in a locked file. Participant names will only appear on the research consent form and this master list. They will not appear on any data sheets or in any data files kept in the laboratory. Names or other information that could be used to identify individuals will not appear when results of the study are presented or published. Video records maintained will be altered to disguise participant appearance (i.e. no faces or identifiable marks such as tattoos will be shown). The video files will be used to quantify movement patterns of subjects during the balance tests, as well as a visual record of the experiment. They are filmed from behind the participants, so that facial images are not recorded. All research records, including video records, are kept on computers accessible only to study staff or in locked archives.

If any subject chooses to withdraw from the study at any point they will be given the choice as to whether they want their data or video deleted or if it can still be included in our analyses. This will be documented in a revocation form.

Subject confidentiality during identification and recruitment will be protected in the following ways. Lower limb prosthesis users that are recruited during clinical visits will be approached by their prosthetist in a private clinic room without any other patients present.

Data collections will occur with a single subject at a time and take place in our lab space in the UIC Biomechanics Lab (Room 198), with only the necessary research personnel present.

The principal investigator, and properly trained research personnel will be the only individuals who will have access to the data. All data will be coded, with the master list linking subjects names, emails, and addresses linked to study ID # kept in a locked file in the PI's office, separate from the location of data storage. This master list is being kept to aid in scheduling multiple study visits. No private health information is being collected.

13.3 Unanticipated Problems

Unanticipated events will be reported to IRB in a timely manner.

14.0 References

1. Jaegers, S. M. H. J., Arendzen, J. H. & de Jongh, H. J. Changes in hip muscles after above-knee amputation. Clin Orthop Relat Res. 1995;319:276-84.
2. Burger H, Valencic V, Marincek C, Kogovsek N. Properties of gluteus maximus in above-knee amputees. Clin Biomech. 1996;11(1): 35–8.
3. Sherk VD, Bemben MG, Bemben DA. Interlimb muscle and fat comparisons in persons with lower-limb amputation. Arch Phys Med Rehabil. 2010;91(7):1077-1081.
4. Putz C, Block J, Gantz S, et al. Structural changes in the thigh muscles following trans-femoral amputation. Eur J Orthop Surg Traumatol. 2017;27(6):829-835.
5. Ryser DK, Erickson RP, Cahalan T. Isometric and isokinetic hip abductor strength in persons with above-knee amputations. Arch Phys Med Rehabil. 1988; 69(10):840–5.
6. James U. Maximal isometric muscle strength in healthy active male unilateral above-knee amputees, with special regard to the hip joint. Scand J Rehabil Med. 1973;5(2):55-66.
7. Rutkowska-Kucharska A, Kowal M, Winiarski SXA. Relationship between asymmetry of gait and muscle torque in patients after unilateral transfemoral amputation. Appl Bionics Biomech. 2018:1-9.
8. Ranz EC, Wilken JM, Gajewski DA, Neptune RR. The influence of limb alignment and transfemoral amputation technique on muscle capacity during gait. Comput Methods Biomech Biomed Engin. 2017;20(11):1167-1174.
9. Leijendekkers RA, Marra MA, Ploegmakers MJM, et al. Magnetic-resonance-imaging-based three dimensional muscle reconstruction of hip abductor muscle volume in a person with a transfemoral bone anchored prosthesis: A feasibility study. Physiother Theory Pract. March 2018:1-10.
10. Robinovitch SN, Heller B, Lui A, Cortez J. Effect of strength and speed of torque development on balance recovery with the ankle strategy. J Neurophysiol. 2002;88(2):613-620.
11. Allet L, Kim H, Ashton-Miller J, De Mott T, Richardson JK. Frontal plane hip and ankle sensorimotor function, not age, predicts unipedal stance time. Muscle Nerve. 2012;45(4):578-585.
12. Moirenfeld I, Ayalon M, Ben-Sira D, Isakov E. Isokinetic strength and endurance of the knee extensors and flexors in trans-tibial amputees. Prosthet Orthot Int. 2000;24(3):221-225.
13. James U, Oberg K. Prosthetic gait pattern in unilateral above-knee amputees. Scand J Rehabil Med.1973;5(1):35-50.
14. Friel K, Domholdt E, Smith DG. Physical and functional measures related to low back pain in individuals with lower-limb amputation: An exploratory pilot study. JRRD. 2005;42(2):155.
15. Nolan L. A training programme to improve hip strength in persons with lower limb amputation. J Rehabil Med. 2012;44(3):241-248.
16. Russell Esposito E, Miller RH. Maintenance of muscle strength retains a normal metabolic cost in simulated walking after transtibial limb loss. PLoS ONE. 2018;13(1).
17. Raya MA, Gailey RS, Fiebert IM, Roach KE. Impairment Variables Predicting Activity Limitation in Individuals with Lower Limb Amputation. Prosthet Orthot Int. 2010;34(1):73-84.
18. Pauley T, Devlin M, Heslin K. Falls sustained during inpatient rehabilitation after lower limb amputation: prevalence and predictors. Am J Phys Med Rehabil. 2006;85(6):521-532.

19. Pauley T, Devlin M, Madan-Sharma P. A single-blind, cross-over trial of hip abductor strength training to improve Timed Up & Go performance in patients with unilateral, transfemoral amputation. J Rehabil Med. 2014;46(3):264-270.
20. van Velzen JM, van Bennekom CA, Polomski W, Slootman JR, van der Woude LH, Houdijk H. Physical capacity and walking ability after lower limb amputation: a systematic review. Clin Rehabil. 2006;20(11):999-1016.
21. James U. Effect of physical training in healthy male unilateral above-knee amputees. Scand J Rehabil Med. 1973;5(2):88-101.

APPENDICES

[Add appendices to your protocol here. Delete any appendices that are not applicable to your research.]

Eligibility Checklist

Case Report Forms (CRFs)

Data Collection Tables/Forms

Questionnaires