Clinical Outcomes with MPKs vs. Powered Prosthetic Knees by K4-level Transfemoral Amputees

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1. Background and Introduction

Transfemoral amputation (TFA) results in significant changes in body structures which impact function, including bipedal activities essential in community living. Mechanical knees and microprocessor-controlled prosthetic knees (MPKs), such as those shown in **Figure 1** below, are the current standards of care and can replace some of the lost function due to TFA, but not all. This is evidenced by the fact that individuals with TFA have been shown to have increased metabolic energy expenditure [1, 2], decreased walking speed [3, 4], increased frequency and fear of falls and stumbles [5, 6], decreased balance [7, 8], reduced activity levels [9, 10], and increased difficulty navigating slopes [11], stairs [12], and uneven terrain [13]. In addition, persons with TFA are at much greater risk of developing long-term secondary health problems, such as osteoarthritis, osteoporosis, higher rates of hip replacement surgeries, residual limb discomfort, low back pain, weight gain, and cardiovascular disease [14, 15]. These increased risks have been associated with the abnormal biomechanical effects of utilizing passive prostheses, which are unable to restore the concentric power at the knee and ankle joints needed for typical biological gait [16].

***Figure 1** | Examples of commercially-available prosthetic knees: (A) Otto Bock C-leg, (B) Össur Mauch®, (C) Össur Rheo®, (D) Össur Power Knee™.*

Powered prosthetic knees have the potential to restore lost knee power. There is currently one commercially-available powered prosthetic knee (Össur's Power Knee™ (PK), Iceland; **Figure 1D**) with others under development. Like traditional MPKs, powered knees detect the person's activity, but unlike MPKs, powered knees are able to provide power at the appropriate time to assist the user in a number of ambulatory tasks. For example, powered knees can actively lift the foot during swing flexion to increase ground clearance independent of the walking speed or type of activity. Possibly most advantageous, powered knee extension assists when standing up from a chair and walking up slopes, as well as allowing for step-over-step stair ascent. These advantages intend to reduce the burden to the non-amputated contralateral limb.

Studies have been conducted to validate the claims that active knee flexion and extension assist the user to achieve more symmetric and biomimetic mechanics, with the goal of ultimately reducing overuse injuries and wear and tear on the intact limb. These studies examined level walking [16, 17, 18], sit-to-stand and stand-to-sit activities [19-22], walking up and down slopes [23], and walking up and down stairs [23]. Benefits were shown in areas such as energy expenditure during level walking [16] and ramp ascent [23], improved biomechanics and symmetry during sit-to-stand [20, 21], stairs and ramps [23], and level walking [17, 18], as well as perceived exertion during long-distance ambulation [18]. However much of this work was performed in a laboratory setting making translation of these findings to community use unclear. Similarly, the limited testing that has been performed in a community environment has been on Medicare Functional Classification Level 3 (i.e., K3) individuals [24] who entered the study as non-MPK users, with only three patients completing the full protocol. There is a lack of testing outside the laboratory on active individuals with TFA and therefore, community testing of individuals with TFA classified as K2, K3 or K4 ambulators is needed to guide clinical decision making and improve clinical outcomes.

2. Study Rationale

This study will focus on investigating the tradeoffs between powered knees and traditional MPKs to identify the prosthetic knee that is best suited for users during different tasks. We will assess measured, observed, and self-reported outcomes achieved through real-world use of these prosthetic knees.

The results of this study will (1) provide initial evidence to guide clinical prescription and use of powered knee technologies for K2, K3 or K4-level individuals with sound scientific data, (2) provide pilot data for a larger clinical trial to further inform the evidence-based prescription of powered knee technologies across multiple K-levels, and (3) obtain data that can be disseminated to other researchers and inform the design of future powered prosthetic knees by understanding the needs of users and identifying the features and functions that are most valuable to these patient populations, as well as evaluating the capabilities and limitations of current devices.

3. Outcomes

To achieve our goals, we will explore the following specific aims:

Specific Aim 1: To evaluate the longitudinal ***mobility*** of individuals with TFA with each prosthetic knee by monitoring activity parameters and assessing performance on functional measures and activities representative of community participation.

Specific Aim 2: To evaluate the longitudinal ***safety*** of individuals with TFA with the use of each prosthetic knee by monitoring measures of balance confidence, exertion, and fatigue, as well as the number of falls.

Specific Aim 3: To evaluate the longitudinal ***well-being*** of individuals with TFA with the use of each prosthetic knee by soliciting feedback on self-reported measures of health-related quality of life.

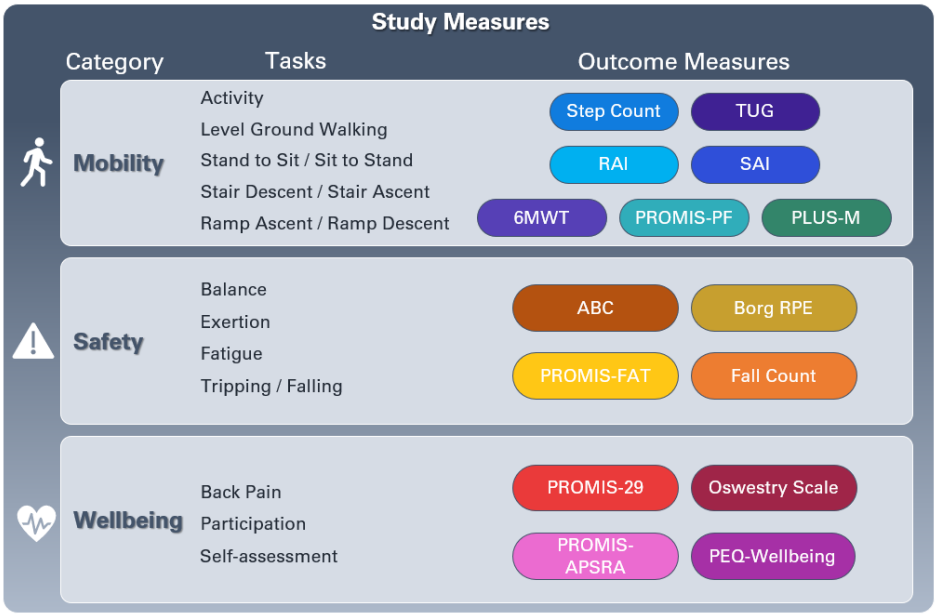

Figure 2 | *Study outcome measures*

To address our specific aims, we will administer a suite of physical and self-report measures to assess functional and perceived differences between the knee conditions, similar to what was performed by Hafner, et. al. [24] (**Figure 2**). We recognize that we have a large number of assessments; however, as a pilot study, we will seek to capture as much information as possible from a small number of individuals to ensure that the follow-on, larger full-scale clinical trial will focus on the most relevant measures.

4. Study Design

We plan to perform a pilot longitudinal randomized crossover study to compare the effects of power at the knee in individuals with unilateral transfemoral amputation (**Figure 3**). The two interventions, or conditions, to be tested are: (A) a powered prosthetic knee and (B) an MPK. For this study we will recruit individuals who are currently MPK users; therefore, for the MPK condition, they will wear their usual prosthesis (e.g. Otto Bock C-leg, Össur Rheo, etc) as they represent the current standard of care. This will be recorded as a potential confounder in post-hoc analysis. For the powered knee condition, each subject will be provided with the Össur Power Knee, which is the only powered knee that is commercially available at this time.

The order these conditions are tested in will be randomized across subjects. Block randomization using a previously developed custom software based on random number generation will be used to equally distribute the subjects into the 2 possible intervention orders (AB or BA). For each condition, the subject will be trained on and acclimated to the device during the first month of the take-home period, and then will continue to wear it at home after training for a total of three months per condition. There may be seasonal effects due to the timing of when the various test conditions are administered, however, we plan to offset these effects with condition randomization, multiple site testing, and staggered start times.

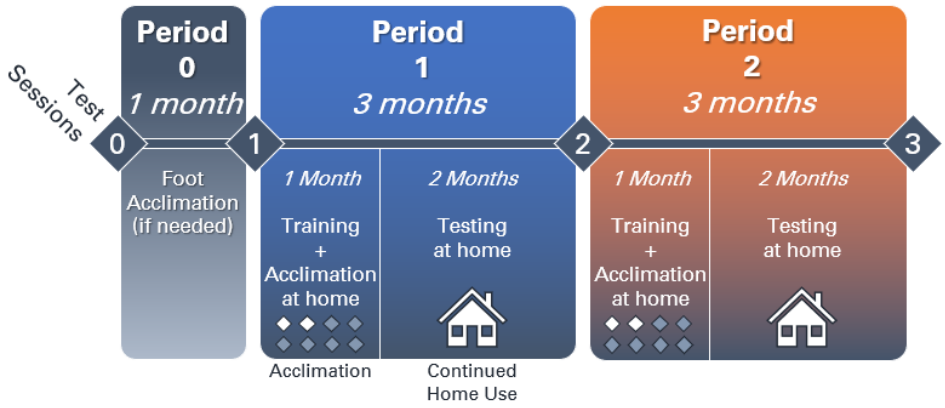

***Figure 3** | Study Design - Longitudinal Randomized Crossover Study*

Testing will consist of test sessions, training sessions, at-home wear of the device, and functional and self-report assessment at the end of each intervention condition (**Figure 3**). If the subject's current foot is not compatible with the Power Knee, they will be provided with a commercially available prosthetic foot for the study. In this case, the subject will be given an initial acclimation period of 1 month on the new foot before starting interventional testing.

After receiving IRB and HRPO (US Army Human Research Protection Office) approval, subjects will be recruited and screened for eligibility. If they are eligible and decide to participate, they will be scheduled for their first site visit. They will either be consented over the phone before their first site visit or at the first site visit ('1' in **Figure 3**). If over the phone, study staff will use the telephone script to confirm eligibility and guide the subject through consent form details. Subjects will be provided the informed consent form to read through entirely before signing, and are encouraged to ask questions at any time.

Prior to each condition, each subject will be fit and aligned on the knee by a trained certified prosthetist. An activity monitor (such as the GeneActiv™) will be worn by the subject. As we have done in prior studies, we will use the activity monitor to track the number of steps the subjects take in each condition. Each subject will wear the same foot for all study periods for comparability between the two knee conditions.

The subject will wear the knee being tested at home for three months. During the first month of each condition, subjects will be given time to acclimate to the knee being tested. Subjects will participate in at least two, but up to eight, 1 hour training sessions. At a minimum, each subject will receive one training session to learn how to properly use each device for a variety of daily activities and a second session to demonstrate retention of the learned skills. The subject will continue training until they show retention of the understanding and/or proficiency of the device functions or until they have received eight training sessions, whichever comes first. After 8 training sessions, they will have completed all of the available training and will therefore continue with the study at their current proficiency level. For the powered knee condition, we will work with trained and experienced clinicians, consulting prosthetic knee manufacturers as needed, to develop the training protocol and determine proficiency.

Subjects will be asked to continue to wear the knee full time for the remainder of the three month take-home period. Through Hanger's current patient care system, we will have the ability to push out a digital to the patient's phone asking them whether they have experienced a recent fall. If they respond positively that they had a fall, follow up questions can be asked to get more specific details about the fall. After three months of at-home wear, the subject will return for the second test visit. During that visit, functional tests and self-report surveys will be administered. At the completion of the second test visit (Period 1), the subject will then be fit and aligned on the prosthetic knee condition for Period 2. The training, at home wear, and in-clinic assessments will be repeated for the next knee condition. The overall study plan and schedule is summarized in **Table 1** below.

Table 1 | *Subject study schedule*

	Sequence	Duration	Description
⓪	Period #0	1 month	If the subject's current foot is not compatible with the Power Knee, they will be provided a foot for the study. They will be given an acclimation period of 1 month on the provided study foot.
◆	Test Session #1	2 hours	The subject will be fit with a prosthetic knee configuration and an activity logger. They will conduct standardized functional tests and assessments.
①	Period #1	3 months	First three-month period of the study. Three months of using the prosthetic knee at home.
◇	Training Sessions	1 hour /each	One-hour sessions will be scheduled during the first month of the take-home period for training on walking with a prosthetic knee configuration. Two to eight sessions will be required. At the first and last training sessions, standardized functional tests and assessments will be conducted.
◆	Test Session #2	4 hours	The subject will conduct standardized functional tests and assessments on the first knee configuration. They will then be fit with their second prosthetic knee configuration and an activity logger.
②	Period #2	3 months	Second three-month period of the study. Three months of using the prosthetic knee at home.
◇	Training Sessions	1 hour /each	One-hour sessions will be scheduled during the first month of the take-home period for training on walking with a prosthetic knee configuration. Two to eight sessions will be required. At the the first and last training sessions, standardized functional tests and assessments will be conducted.
◆	Test Session #3	2 hours	The subject will conduct standardized functional tests and assessment. This is the final study event. Any study device or equipment will be returned, and their prosthesis reconfigured to its original state.

5. Study Population

The proposed work will include recruiting persons with transfemoral amputation for take-home testing of two prosthetic knees in a randomized crossover design. A statistical power analysis revealed that 12 subjects would be required to achieve the desired statistical power to determine whether individuals are more active when wearing a powered knee than a traditional MPK prosthesis as measured by the daily number of steps taken. This power analysis aligns with the recommendation of Moore, et al. [35] to include 12 subjects to estimate average values and variances of our specific outcome variables in our target population. We recognize that this pilot study may not demonstrate definitive evidence for a treatment effect of the intervention. However, it provides the means to gather the data and experience necessary to optimize value and practicality for a subsequent clinical trial. Therefore, based on the above, this study will require data from 12 individuals with transfemoral limb absence who use an MPK. However, we will target recruitment of 15 individuals for participation, to allow for up to 20% dropout.

While the recruitment of anything above a modest number of people with a limb absence can be challenging, the multiple locations of Hanger Clinics will help mitigate this risk and increase our pool of potential subjects from multiple geographic areas. Dr. Shane Wurdeman has been able to preemptively identify the locations within Hanger's network of approximately 800 prosthetic clinics nationwide to focus recruitment at those sites with a

large population of transfemoral, K4, K3 and K2 prosthesis users. If recruitment challenges are encountered, he will onboard additional clinical sites as needed to mitigate recruitment issues.

6. Participant Eligibility

Up to 15 people will be recruited for testing. Individuals who meet the following inclusion criteria will be included in the study:

- Are at least 18 years old
- Unilateral transfemoral prosthesis user (limb absence between the knee and hip)
- Current user of a microprocessor-controlled knee (MPK)
- Have adequate clearance between distal end and ground for necessary knee and foot components
- Medicare Functional Classification Level (K-Level): 2, 3, or 4
- Socket-Comfort Score: 6 or above to ensure adequate socket fit
- Six months or more experience on a prosthesis
- Body weight between 50kg and 116kg (110lbs - 256lbs)

Exclusion criteria are:

- Present injuries to residual limb or contralateral leg affecting functional ability
- Socket issues/changes in the last 6 weeks
- Users with bone-anchored implants

Subjects can be excluded at the discretion of the investigator for other unforeseen disqualifying criteria (such as specific cognitive issues, etc.). Subjects in this study will not be discriminated by sex/gender or race/ethnicity.

Using a knee that the subject is unfamiliar with may increase the risk of falling. Therefore, pregnant women should not participate in the study and will be screened by self-disclosure.

7. Study Methodology

Timeline: Subject participation in this study will span six months with two, 3-month at-home study periods. Subjects will be asked to attend 2 to 8 training visits, conduct normal activity at home, document their falls, and complete a series of functional tests and self-report surveys upon their return to the clinic. Site visits will take approximately 2 to 4 hours. Additional site visits may be scheduled if issues arise (issues with alignment, time constraints, etc.).

If the subject's current foot is not compatible with the Power Knee, they will be provided a standard foot for the study and given an initial acclimation period of 1 month before site visit 1. In this case, subjects will be consented before (over the phone) or during their initial visit in which the prosthetist will align them on the foot provided for this study. Subjects are free to terminate a session and their participation in this study whenever they wish. The specific study events are detailed below.

Site Visit <1>

If the subject has not yet been consented, they will begin the process of informed consent where all of the details of the research study will be explained at this start of this visit. Subjects are allowed to take the consent form home with them and show it to friends, family, and their physician in order to make an informed decision to participate in the study. Once consented, demographic information, including height, weight, and type of prosthetic foot and socket suspension, will be collected from the subject.

The subject will then be fit and aligned with the first prosthetic knee by a certified prosthetist. An activity monitor will be worn by the subject to monitor daily step count.

This visit will take up to 2 hours.

Period 1: At-Home Participation Months 1-3

During the first month of the take-home period, subjects will be trained on the knee they are wearing and allowed time to acclimate to it at home. At a minimum, each subject will receive one training session to learn how to properly use each device for a variety of daily activities and a second training session to demonstrate retention of the learned skills. At the beginning of the first training session, standardized functional tests and assessments will be conducted.

Subjects will be asked to complete a series of functional tests and self-report surveys to assess their mobility, safety, and well-being. The measures that we may use are:

Specific Aim 1- Mobility
For aim 1, we plan to administer outcome measures such as: step count, the Six Minute Walk Test (6MWT) [25], Stair Assessment Index (SAI) [26]; Ramp Assessment Index (RAI) [26]; TUG [27]; Patient Reported Outcomes Measures Information System (PROMIS) Physical Function (-PF) short form [24]; and the Prosthetic Limb Users Survey of Mobility (PLUS-M) [28].

Specific Aim 2 - Safety
For aim 2, we plan to administer outcome measures such as: the Activities-Specific Balance Confidence (ABC) scale [29], the Borg Rating of Perceived Exertion Scale (RPE) [30], heart rate (to calculate the Physiological Cost Index (PCI) [36], the PROMIS- Fatigue (PROMIS-FAT) short form [29], and number and details of self-reported falls.

Specific Aim 3 – Wellbeing
For aim 3, we plan to administer outcome measures such as: PROMIS-29 short form [31], the Oswestry Disability Index (ODI) [32], Prosthesis Evaluation Questionnaire-Well Being (PEQ-Well Being) [33], and the PROMIS-Ability to Participate in Social Roles and Activities (PROMIS-APSRA) short form [34].

After completing these measures, the subject will complete their initial training session for the first knee condition.

The subject will continue training until they show retention of the understanding and/or proficiency of the knee functions or until they have received eight training sessions, whichever comes first. At the end of the last training session, standardized functional tests and assessments will be conducted (such as those described in training session 1). Then during the following two months, the subject will be asked to continue using the knee full-time.

Study staff may call or email the subject periodically to check-in and answer any questions they may have. A digital fall questionnaire will be delivered at most weekly through a HIPAA secure system to the patient's phone. If they respond positively that they had a fall, follow up questions can be asked to get more specific details. The subject may be asked to provide additional notes periodically to document their problems, experiences, and feedback.

This portion of the study will be three months long.

Site Visit <2>

After three months of at-home wear, the subject will return for the second test visit. Subjects will be asked to complete a series of functional tests and self-report surveys on the first knee configuration.

Once the subjects have completed the functional tests and assessments, the activity monitor will be removed, and the knees will be swapped. The subject will be fit and aligned with the second prosthetic knee by a certified prosthetist. The activity monitor will then be placed back on the subject for condition 2.

This visit will take approximately 4 hours.

Period 2: At-Home Participation Months 4-6

This period is the same as Period 1, except subjects will be testing and training on the second prosthetic knee.

This portion of the study will be three months long.

Site Visit <3>

At the end of Period 2, subjects will return to the clinic. They will be asked to complete a series of functional tests and self-report surveys on the second knee configuration. After completing these measures, the activity monitor will be removed, and the subject will be set back up on their usual prosthetic knee and foot by a certified prosthetist. At this time, the subject has completed the study.

This visit will take approximately 2 hours.

8. Study Conduct

Subjects will be screened and consented for eligibility criteria. If they decide to participate, they will be set up with the first prosthetic knee being tested. The study will consist of two, three month periods where subjects will be trained on the knees, use the prosthetic knees at homes and document any falls and feedback on the knees. At the beginning and end of each knee condition, as well as at their final training session, subjects will complete a series of functional tests and self-report surveys.

Subjects may withdraw at any time by simply telling the investigators they wish to stop their participation.

If a subject withdraws from the study, the data that were collected from them can still be used, and the withdrawn subjects may be replaced with a new subject. Deviations from the protocol that increase risks for subjects will be reported to WCG and HRPO for approval prior to being implemented.

Subjects will be compensated for the Site Visit milestones described in **Section 7: Study Methodology**. They will receive $50 for Site Visit 1, $100 for Site Visit 2, and $150 for Site Visit 3, for a total of $300 for completing all visits. Subjects will also receive $50 for completing 2 months, $100 for completing 4 months, and $125 for completing 6 months of the study, for a total of $275 for finishing the take-home portion of the study. Upon completion of the study and return of study materials, subjects will receive an additional $200. The total anticipated payment for this study is $775 per subject.

9. Study Treatment

The Össur Power Knee is currently the only commercially-available powered prosthetic knee. The intervention being tested in this study is the newest version of this product, Össur Power Knee III™ (**Figure 4**).

Figure 4 *| Rendering of the Össur Power Knee III™*

The Power Knee III contains design improvements to optimize features such as the control strategy, weight, and battery life. According to the Power Knee's instructions for use, the device is comprised of a proximal pyramid adapter, motor, power button and status indicator, battery, charging port, battery indicator, battery button, and distal pyramid connector.

A second intervention, the subject's usual MPK, will also be tested as a baseline measure. All MPKs used for this condition (i.e., Otto Bock C-leg, Össur Rheo, Freedom Innovations Plié, and Blatchford Orion) are commercially available. This configuration will be the same knee system the subject usually uses and will be tested for the purpose of comparing outcomes between their existing knee and the provided powered knee device.

Subjects will be instructed upon the device design and features and allowed time to practice operating the device using conventional strategies for powered knee prostheses. Fittings and trainings will be conducted with a certified prosthetist and/or physical therapist.

10. Evaluation of Adverse Events

The main risk of the devices, inherent to all lower limb prostheses, is injury from tripping, falling, or losing balance. Changing from the user's usual MPK to the Power Knee and back may increase the risk of falls. The user may also experience fatigue during in-clinic testing. To mitigate the risk of tripping, falling, or losing balance, a certified prosthetist will fit the subject with all prosthetic components. Users will be provided with instructions, training, and acclimation periods for each knee configuration. Safety methods (such as handrails, parallel bars, spotters, gait belts, overhead harnessing, etc.) will be available during in-clinic testing to mitigate fall or trip hazards. Training will be conducted in a clinic setting before subjects are sent home with any new devices. If the user feels as though the prosthetic knee is giving them trouble at home, they may schedule a visit with their prosthetist to fix any issues, or configure them back on their usual knee if the problem persists. To mitigate any fatigue during in-clinic training and testing, rests and break periods will be allowed and encouraged at the subject's discretion to ensure they are comfortable while training and performing tests with the study knees.

All unanticipated problems involving risk to subjects or others, serious adverse events related to participation in the study and subject deaths related to participation in the study will be promptly reported to the WCG IRB and HRPO. A written description of the adverse event will be stored in the study file maintained by the Principal Investigator (PI). Also, the protocol will be reviewed in light of the adverse event to determine if modifications need to be made to prevent the event from occurring again. Major modifications to the research protocol and any modifications that could potentially increase risk to human subjects must be submitted to the WCG IRB and HRPO for approval prior to implementation.

11. Ethical Considerations

Individuals receiving the powered knee will get to experience an extended at-home trial period. Beyond this, the powered prosthetic knee device provides no further known direct benefit to the subjects. Their participation in this study will expand the knowledge of the prosthetic community by further understanding how users benefit from each of the prosthetic knees being tested. This research will in turn help physicians and prosthetists make more informed decisions when determining which devices are best for their patients.

The protocol, consent form, and recruitment flyer will require IRB review and approval. The principal investigators will be in continuous communication with WCG IRB HRPO. Subjects' participation is voluntary, and they may withdraw from participation in the study at any time by simply saying that they wish to stop. The investigators may choose to terminate a subject's participation if he or she experiences discomfort or injury. In addition, subjects will be given any new information which is discovered during the course of the study which may influence subjects' willingness to continue the study. If they desire to do so, subjects' will also have the option to discuss any concerns regarding the study activities or the investigators with an impartial staff member of the IRB, whose duty it is to hear and review such concerns and provide advice or take any other appropriate actions.

The investigators will ensure the anonymity of all subjects in this study. After completing the consenting process, subjects will be assigned a unique alpha-numeric identification number. The number will be used on all test data associated with the subject. No personal identifiers will be associated with the data collected from the subjects during the study. The PI will have a master document linking the subject name with ID number, and it will be stored on a password protected computer, with only the PI and approved study staff having access to the master

list. Only the de-identified data will be shared with Liberating Technologies, Inc. using subject and condition number for data analysis. Data will be stored in a secure manner depending on the media: either a password protected computer with access limited to the co-investigators, or in a locked filing cabinet in the investigator's office. A copy of the test data will also be retained by the PI in the program folder, also stored in a secured manner. As with anything, there is the potential of a data breach, however the described steps taken to keep subject information secure will minimize this risk.

12. Study Monitoring and Oversight

Liberating Technologies, Inc., as the clinical trial sponsor, plans to meet all requirements outlined in US federal regulations and International Council for Harmonisation (ICH) E6 for monitoring to ensure that site investigators comply with the protocol, all regulations, and Good Clinical Practice (GCP). The PI will ensure the rights and well-being of human subjects are protected, all data reported is accurate and complete, and that the conduct of the trial is in compliance with the approved protocol, GCP, and other regulations.

De-identified data, photos, and videos will be kept indefinitely to show in scientific presentations and publications. Photos will not contain any identifying information about the subject. Photos will not include the subject's face or any identifying marks such as tattoos. If identifying photos happen to be received from a subject, they will be de-identified by either cropping or blurring using photo-editing software.

Additionally, representatives of the United States Army Medical Research Acquisition Activity (USAMRAA) are eligible to review research records as a function of their responsibility to protect subjects in research.

13. Investigational Product Management

All devices being tested are commercially available prosthetic knees.

14. Data Analysis

The data collected in the in-clinic and take-home portions of this study will include number of steps and number of self-reported falls, and a series of standard outcomes measures, including: 6MWT, SAI, RAI, TUG, PROMIS-PF short form, PLUS-M, ABC, RPE, PROMIS-Fat, PROMIS-29, ODI, PEQ-Well Being, and PROMIS-APSRA short form.

The primary statistical analysis will be led by Dr. Newton and will employ a linear mixed model. It will not include carryover effects as the training and acclimation period in the first month of each condition will constitute the washout period for the prior knee. Additional predictors will include a fixed effect for gender and MPK as well as a random effect for test clinic to account for potential differences between sites.

15. References

1. Waters, R.L., et al., Energy cost of walking of amputees: the influence of level of amputation. J Bone Joint Surg Am, 1976. 58(1): p. 42-6.
2. Traugh, G.H., P.J. Corcoran, and R.L. Reyes, Energy expenditure of ambulation in patients with above-knee amputations. Arch Phys Med Rehabil, 1975. 56(2): p. 67-71.

3. Jaegers, S.M., J.H. Arendzen, and H.J. de Jongh, Prosthetic gait of unilateral transfemoral amputees: a kinematic study. Arch Phys Med Rehabil, 1995. 76(8): p. 736-43.
4. Boonstra, A.M., et al., The gait of unilateral transfemoral amputees. Scand J Rehabil Med, 1994. 26(4): p. 217-23.
5. Miller, W.C., et al., The influence of falling, fear of falling, and balance confidence on prosthetic mobility and social activity among individuals with a lower extremity amputation. Arch Phys Med Rehabil, 2001. 82(9): p. 1238-44.
6. Miller, W.C., M. Speechley, and B. Deathe, The prevalence and risk factors of falling and fear of falling among lower extremity amputees. Arch Phys Med Rehabil, 2001. 82(8): p. 1031-7.
7. Buckley, J.G., D. O'Driscoll, and S.J. Bennett, Postural sway and active balance performance in highly active lower-limb amputees. Am J Phys Med Rehabil, 2002. 81(1): p. 13-20.
8. Miller, W.C. and A.B. Deathe, A prospective study examining balance confidence among individuals with lower limb amputation. Disabil Rehabil, 2004. 26(14-15): p. 875-81.
9. Halsne, E.G., M.G. Waddingham, and B.J. Hafner, Long-term activity in and among persons with transfemoral amputation. J Rehabil Res Dev, 2013. 50(4): p. 515-30.
10. Stepien, J.M., et al., Activity levels among lower-limb amputees: self-report versus step activity monitor. Arch Phys Med Rehabil, 2007. 88(7): p. 896-900.
11. Vrieling, A.H., et al., Uphill and downhill walking in unilateral lower limb amputees. Gait Posture, 2008. 28(2): p. 235-42.
12. Ramstrand, N. and K.A. Nilsson, A comparison of foot placement strategies of transtibial amputees and able-bodied subjects during stair ambulation. Prosthet Orthot Int, 2009. 33(4): p. 348-55.
13. Vrieling, A.H., et al., Obstacle crossing in lower limb amputees. Gait Posture, 2007. 26(4): p. 587-94.
14. Naschitz, J.E. and R. Lenger, Why traumatic leg amputees are at increased risk for cardiovascular diseases. QJM, 2008. 101(4): p. 251-9.
15. Kulkarni, J., et al., Chronic low back pain in traumatic lower limb amputees. Clin Rehabil, 2005. 19(1): p. 81-6.
16. Jayaraman, C., et al., Impact of Powered Knee-Ankle Prosthesis on Low Back Muscle Mechanics in Transfemoral Amputees: A Case Series. Front Neurosci, 2018. 12: p. 134.
17. Creylman, V., et al., Assessment of transfemoral amputees using a passive microprocessor-controlled knee versus an active powered microprocessor-controlled knee for level walking. Biomed Eng Online, 2016. 15(Suppl 3): p. 142.
18. Pasquina, P., et al., Case Series of Wounded Warriors Receiving Initial Fit PowerKnee Prosthesis. Journal of Prosthetics and Orthotics, 2017. 29(2): p. 88-96.
19. Simon, A.M., et al., Improved Weight-Bearing Symmetry for Transfemoral Amputees During Standing Up and Sitting Down With a Powered Knee-Ankle Prosthesis. Arch Phys Med Rehabil, 2016. 97(7): p. 1100-6.
20. Wolf, E.J., et al., Comparison of the Power Knee and C-Leg during step-up and sit-to-stand tasks. Gait Posture, 2013. 38(3): p. 397-402.
21. Highsmith, M.J., et al., Kinetic asymmetry in transfemoral amputees while performing sit to stand and stand to sit movements. Gait Posture, 2011. 34(1): p. 86-91.
22. Quinonez, E., R.S. Gailey, and K. Lechler. Biomechanics of sit-to-stand and stand-to-sit movements in unilateral transfemoral amputees using powered and non-powered prosthetic knees. in OTWorld Congress. 2014. Leipzig, Germany.
23. Wolf, E.J., et al., Assessment of transfemoral amputees using C-Leg and Power Knee for ascending and descending inclines and steps. J Rehabil Res Dev, 2012. 49(6): p. 831-42.
24. Hafner, B.J. and R.L. Askew, Physical performance and self-report outcomes associated with use of passive, adaptive, and active prosthetic knees in persons with unilateral, transfemoral amputation: Randomized crossover trial. J Rehabil Res Dev, 2015. 52(6): p. 677-700.

25. Cox, P.D., et al., Impact of Course Configuration on 6-Minute Walk Test Performance of People with Lower Extremity Amputations. Physiother Can, 2017. 69(3): p. 197-203.
26. Highsmith, M.J., et al., Psychometric Evaluation of the Hill Assessment Index (Hai) and Stair Assessment Index (Sai) in High-Functioning Transfemoral Amputees. Technol Innov, 2016. 18(2-3): p. 193-201.
27. Podsiadlo D (1991) Richardson S The Timed "Up & Go": a test of basic functional mobility for frail elderly person. J Am Geriatr Soc 39(2):142–148
28. Hafner, B.J., et al., Construct Validity of the Prosthetic Limb Users Survey of Mobility (PLUS-M) in Adults With Lower Limb Amputation. Arch Phys Med Rehabil, 2017. 98(2): p. 277-285.
29. Miller, W.C., A.B. Deathe, and M. Speechley, Psychometric properties of the Activities-specific Balance Confidence Scale among individuals with a lower-limb amputation. Arch Phys Med Rehabil, 2003. 84(5): p. 656-61.
30. Borg, G.A., Psychophysical bases of perceived exertion. Med Sci Sports Exerc, 1982. 14(5): p. 377-81.
31. Amtmann, D., et al., Health-related profiles of people with lower limb loss. Arch Phys Med Rehabil, 2015. 96(8): p. 1474-83.
32. Fairbank, J.C. and P.B. Pynsent, The Oswestry Disability Index. Spine (Phila Pa 1976), 2000. 25(22): p. 2940-52; discussion 2952.
33. Legro, M.W., et al., Prosthesis evaluation questionnaire for persons with lower limb amputations: assessing prosthesis-related quality of life. Arch Phys Med Rehabil, 1998. 79(8): p. 931-8.
34. Hahn, E.A., et al., New English and Spanish social health measures will facilitate evaluating health determinants. Health Psychol, 2014. 33(5): p. 490-9.
35. Moore, C.G., et al., Recommendations for planning pilot studies in clinical and translational research. Clin Transl Sci, 2011. 4(5): p. 332-7.
36. MacGregor J. The objective measurement of physical performance with long term ambulatory physiological surveillance equipment (LAPSE). In: Stott FD, Raftery EB, Goulding L, editors. Proceedings of 3rd International Symposium on Ambulatory Monitoring; 1979; London, UK. Academic Press; pp. 29–39.