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IMPACT OF PROSTHESIS USE AND EMBODIMENT ON BALANCE CONFIDENCE, FEAR OF FALLING, AND FALLS IN INDIVIDUALS WITH UPPER LIMB LOSS OR DIFFERENCE

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Impact of Prosthesis Use and Embodiment on Balance Confidence, Fear of Falling, and Falls in Individuals with Upper Limb Loss or Difference

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Abstract

Background/Significance: Evidence suggests prosthesis use and prosthetic embodiment may affect balance confidence, fear of falling, and incidence of falls in individuals with upper limb loss or difference (ULL/D). **Purpose:** The purpose of this study was to evaluate the relationship of prosthesis use and embodiment with balance confidence, fear of falling, and incidence of falls (fallers versus non-fallers) in persons with ULL/D. **Methods:** Participants completed the survey online or over the telephone. A convenience sample was recruited from several sites that targeted the study population. **Results:** Eighty-four participants were included in the study. A non-significant negligible relationship was found between frequency of prosthesis use and balance confidence as well as with fear of falling. A non-significant weak relationship was found between prosthesis embodiment and balance confidence and also with fear of falling for individuals with unilateral and individuals with bilateral ULL/D. Analyses found a weak relationship between embodiment and frequency of prosthesis use in individuals with unilateral ULL/D ($r_s = .49$, $p < .001$) and a strong relationship for individuals with bilateral ULL/D ($r_s = .72$, $p < .001$). A significant difference was found between frequent fallers and non-fallers for balance confidence ($p = .002$) and fear of falling ($p < .001$). **Discussion/Conclusion:** Frequency of prosthesis use was associated with embodiment of the prosthesis; however, neither frequency of prosthesis use nor embodiment influenced the incidence of falls. Balance confidence scores were lower while scores for fear of falling were higher for fallers compared to non-fallers. This suggests these factors may be useful to identify potential fall risk in individuals with ULL/D.

Keywords: Upper limb loss, upper limb difference, prosthesis, embodiment, balance, fear of falling, falls

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With deepest gratitude,

Kristi L. Turner

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Impact of Prosthesis Use and Embodiment on Balance Confidence, Fear of Falling, and Falls in Individuals with Upper Limb Loss or Difference

In 2005, an estimated 41,000 people in the United States lived with upper limb (UL) loss at or above the wrist level, and this number is projected to increase (Ziegler-Graham, MacKenzie, Ephraim, Travison, & Brookmeyer, 2008). Loss of an arm can cause severe disability affecting work and leisure activities and basic independence. The arms are known to play an important role in balance recovery after tripping and gait stability after perturbation (Bruijn, Meijer, Beek, & van Dieen, 2010; Pijnappels, Kingma, Wezenberg, Reurink, & Van Dieën, 2010). Research with non-impaired individuals suggests that restricting one arm to their side during balance testing resulted in more severe, longer, and more frequent losses of balance (Shafeie, Manifar, Milosevic, & McConville, 2012). It is unknown whether similar balance results would be found in individuals with upper limb loss.

Balance confidence is a measure of an individual's perception of their ability to perform an activity without losing balance or becoming unsteady (Powell & Myers, 1995), and has been correlated with postural control in populations such as Parkinson's disease (Lee, Altman, McFarland, & Hass, 2017; Pompeu et al, 2016). Postural control, or the ability to maintain a state of balance during any activity (Pollock, Durward, & Rowe, 2000), has been reported to improve in individuals with ULL/D who wore their prosthesis more ((Imaizumi, Asai, & Koyama, 2016). Evidence from Imaizumi et al.'s study (2016) suggests that individuals with ULL/D who had improved postural control would also have improved balance. However, Major (2019) found that individuals with ULL/D generally did not exhibit low balance confidence. It is unknown whether the low balance confidence reported by individuals with ULL/D was affected by the frequency of their prosthesis use.

Despite individuals with ULL/D not having low balance confidence, Major (2019) found they were more likely to experience two or more frequent falls. Individuals with ULL/D who have experienced falls may also have a fear of falling (Tajali et al., 2017). As with reported balance confidence, it is also unknown whether prosthesis use affects frequency of falls, and the relationship between prosthesis use and fear of falling has not been explored in this population. In addition, a recent study identified prosthesis use as a contributing factor that increases the likelihood of sustaining a fall in this population (Major, 2019); a follow up study found that prosthesis use increases postural demands (Major, Shirvaikar, Stine, & Gard, 2019). Currently, no studies have evaluated frequency of prosthesis use which may be a more appropriate measure of the incidence of falls. There is a gap in the literature concerning the relationship between prosthesis use and balance confidence, fear of falling, and incidence of falls in individuals with ULL/D. Another factor that may influence these variables is embodiment.

Embodiment is when individuals with limb loss view their prosthesis as an extension of themselves (Dornfield et al., 2016). How often individuals wear their prosthesis and the extent they experience prosthesis embodiment may play a role in balance confidence, the incidence of falls, and fear of falling given the critical role arms play in maintaining one’s functional balance during activity (Shafeie et al., 2012) and overall locomotor stability (Bruijn et al., 2010). However, to date, no studies have looked at the impact of self-reported embodiment on balance confidence, fear of falling, incidence of falls, or frequency of prosthesis use.

The purpose of this study was twofold. First, this study explored the relationship between prosthesis use and balance confidence, incidence of falls, fear of falling. Second, it assessed the relationship between embodiment and balance confidence, incidence of falls, and fear of falling in persons with ULL/D. To meet this purpose, the following primary null hypotheses were addressed:

Prosthesis Use

H0: there will not be a relationship between frequency of prosthesis use and balance confidence;

H0: there will not be a relationship between frequency of prosthesis use and fear of falling;

H0: there will not be a relationship between frequency of prosthesis use and incidence of falls;

H0: there will not be a relationship between frequency of prosthesis use and embodiment.

Embodiment

H0: there will not be a relationship between prosthesis embodiment and balance confidence;

H0: there will not be a relationship between prosthesis embodiment and fear of falling;

H0: there will not be a relationship between prosthesis embodiment and incidence of falls.

The following secondary hypotheses were addressed:

H0: there will not be a difference between balance confidence and incidence of falls, self-reported frequent fallers and non-fallers.

H0: there will not be a difference between fear of falling and incidence of falls, self-reported frequent fallers and non-fallers.

Gaining a better understanding of the role prosthesis use and embodiment play in balance confidence and falls will help clinicians implement appropriate monitoring and rehabilitation interventions to minimize the risk of falls and fall-related injuries. If these factors do affect balance confidence, incorporating measures into clinical settings can provide immediate benefit.

Literature Review

Losing a hand or arm can have a profound impact on an individual's quality of life due to challenges with activities of daily living, employment, and participation in leisure activities (Wijk & Carlsson, 2015). In addition, the loss or absence of an UL has the potential to impact an individual's postural control during daily tasks. Individuals with ULL/D demonstrate asymmetry toward their sound side, despite the use of a prosthesis (Major et al., 2018). In one study, individuals with transradial ULL/D had an increase in lateral tilt of their trunk and head flexion and rotation compared to healthy controls when performing functional tasks from both sitting and standing (Hussaini, Zinck, & Kyberd, 2017). However, it is unknown if these postural changes performed during functional activities affect individuals with ULL/D fall risk or fear of falling.

There is sufficient evidence to support pursuing a better understanding of the relationship of the frequency of prosthesis use and embodiment with balance confidence, fear of falling, and falls in persons with ULL/D. Understanding the perception of these individuals regarding their fall risk can provide useful information for improving screening techniques and interventions. Clinically, answers to this question can lead to better fall prevention programs and minimize the risk of injury for these patients.

Upper Limb Role in Balance

Researchers have acknowledged the important role of the UL in postural control. It has been established that functional performance improves when the UL is used freely during clinical balance and mobility testing, (Milosevic, McConville, & Masani, 2011). Arm movement has also been found to improve the ability to maintain and recover postural balance (Shafeie et al., 2012). Research suggests that the UL may play an important role in balance recovery after tripping and gait stability after perturbation as well (Bruijn, Meijer, Beek, & van Dieen, 2010; Pijnappels et al., 2010). More severe, longer, and frequent losses of balance occur when unable to use the UL during balance testing (Shafeie et al., 2012). When evaluating the role of the UL during trip recovery, younger adults exhibited a preventative strategy by elevating their center of mass and reducing the forward momentum of their body. In contrast, older adults reach forward as a protective response to stop a possible fall (Roos, McGuigan, Kerwin, & Trewartha, 2008). This information again highlights the importance of the UL in balance and fall risk and demonstrates how the reactions of individuals due to a loss of balance may result in a fall.

Compensatory Movements after Upper Limb Loss

Development of asymmetric postures, prosthesis wear, and changes in center of gravity may impair balance in individuals with ULL/D and increase the risk of falls. Studies have identified that compensatory movements in the trunk and proximal UL during reaching tasks were greater in all prosthetic users with ULL/D compared to healthy controls. Compensatory strategies most commonly used were lateral and forward trunk flexion to change the terminal device position (Metzger, Dromerick, Holley, & Lum, 2012). However, Major, Stine, Heckathorne, Fatone, and Gard (2014) found that transradial prosthesis users utilized shoulder abduction and trunk rotation to compensate for a lack of range of motion in the distal extremity of a prosthesis. Newer prosthetic users did not use a consistent movement pattern when completing tasks in repetition (Thies et al., 2017) and repeatable movements only occurred as the user gains experience with the prosthesis (Major et al., 2014). It is unknown if this variability of movement patterns and compensatory movements especially in a new prosthetic user could result in loss of balance or falls especially as they are becoming familiar with their device.

Additionally, arm amputation causes an approximate weight decrease, which may cause those with unilateral ULL/D to develop asymmetric body postures and a shifting of their center of gravity (Bertels, Schmalz, & Ludwigs, 2012). Wijk and Carlsson (2015) found when interviewing individuals with limb loss or absence at the mid-forearm level, that the prosthesis was described as beneficial for body posture and balance and without the prosthesis resulted in asymmetry of the body. This description was also supported in a study of individuals with loss of the UL at the shoulder disarticulation level. Postural asymmetry was reduced by an average of 45%, compensatory movements of the contralateral limb, increased swinging at the elbow and shoulder joint, were decreased, and there was improved body posture when wearing a prosthesis during walking (Bertels, Schmalz, & Ludwigs, 2012). However, nearly 34% of individuals with proximal ULL/D reject their prosthesis (Datta, Selvarajah, & Davey, 2004). For myoelectric and body-powered prosthetic users, rejection rates of 26% and 23% were reported (Biddiss and Chau, 2007). This lack of prosthetic wear after amputation can increase the severity of asymmetric postures over time and changes the individual's center of gravity while they are not wearing the prosthesis (Bertels et al., 2012).

Although individuals with ULL/D at the shoulder disarticulation level had improved body posture when wearing a prosthesis compared to not wearing a prosthesis when walking (Bertels et al., 2012), this is not true for those with transhumeral ULL/D (Topuz et al., 2019). When gait was evaluated in individuals with unilateral ULL/D at the transhumeral level while wearing a prosthesis, they had a minimal arm swing on the side with limb loss which had a negative effect on dynamic balance compared to healthy controls (Topuz et al., 2019). Additionally, Major (2019) reported that individuals with ULL/D were more likely to fall if they used an UL prosthesis. These studies highlight the importance of coordinating movements of both arms for stable balance and recovery (Shafeie, Manifar, Milosevic, & McConville, 2012). However, the impact a prosthesis has on postural control, balance, and fall risk is still largely unknown.

Current Assessment and Treatment of Individuals with Upper Limb Loss or Difference

As previously stated, there is a lack of research quantifying fall risk or fear of falling in individuals with ULL/D, and this lack of knowledge extends to the assessment and treatment of this population. Painter et al. (2009) reported that occupational therapists should assess fear of falling in older adults, as it may be one factor that is related to fall risk and activity restriction. However, when clinicians who work with this population identified key areas in rehabilitation, neither fall risk nor fear of falling were included (NiMhurchadha, Gallagher, MacLachlan, & Wegener, 2013). The findings by Major (2019) found individuals with ULL/D were nearly six times more likely to have repeated falls (2 or more) if they used a prosthesis, suggest further investigation of fall risk is warranted.

In addition, appropriate and useful standardized functional performance assessments for individuals with ULL/D are lacking overall (Wright, 2009). Even the most highly rated self-report measures for use with upper limb loss are not specific to those with ULL/D (Resnik, Borgia, Silver, & Cancio, 2017) and instruments that assess fall risk in this population are absent. Although the Trinity Amputation and Prosthesis Experience Scales (TAPES), was developed for individuals with LL amputation, it has been utilized with individuals with ULL/D and is the closest to assessing ULL/D impact on mobility. Individuals are asked to rate their perceived performance limitations during daily activities, including walking, climbing stairs, as well as during vigorous activities like running. When utilized with individuals with ULL/D, average scores in the area of mobility restriction indicated low levels of mobility impairment (Desmond & MacLachlan, 2005); however, the TAPES does not specifically address balance confidence, fear of falling, or falls. Therefore, it is unknown how these individuals may truly be impacted by their limb loss although research suggests that individuals with ULL/D report a high incidence of falling (Major, 2019). This lack of evidence demonstrates the need for further research to understand fall likelihood in those individuals with ULL/D to assist clinicians in creating better evidenced-based interventions for this population.

Balance confidence. Major (2019), reported that although confidence was high on average in individuals with ULL/D, this factor was a significant contributor to a predictive model of frequent falls (two or more), where lower balance confidence, as scored with the Activities-Specific Balance Confidence (ABC) Scale, was predictive of an increased likelihood of falls. Due to the lack of literature on falls in persons with ULL/D, investigations into individuals with LL loss were used to generate rationale for studying balance confidence in this patient group of interest. Individuals with LL loss were shown to negatively influence balance confidence scores and social activity (Miller & Deathe, 2011). Balance confidence was also associated with performance, perceived mobility capability using a prosthesis, and social activity in individuals with LL amputations (Miller, Deathe, Speechley, & Koval, 2001). Similarly, the ABC Scale scores and fear of falling avoidance behavior were best at predicting future falls in older adults (Landers, Oscar, Sasaoka, & Vaughn, 2016).

Just as further study is needed to describe what is contributing to a fear of falling outside of actual falls in this population, so also could information related to the fear of falling be useful in those with UL/D. Cumulatively these studies help solidify the need to study fear of falling and fall risk in those with ULL/D as this group is often expected to be otherwise high-functioning but also have been reported to experience falls. Understanding their own perceptions of fall risk will help guide effective treatment strategies to prevent falls and subsequent injury.

Falls

Information is scarce in the literature on falls for those with ULL/D. In a survey of 109 individuals with upper limb loss at the wrist or higher, Major (2019) reported that 46% of these individuals experienced at least one fall and nearly a third fell more than once. The most common causes of falls were tripping and loss of balance; 30% reported falling while ascending/descending stairs and another 30% reported falling while walking outdoors (Major, 2019). Remarkably, of fallers, 31.7% indicated their most recent fall resulted in injury with 14.6% requiring medical attention or a hospital visit (Major, 2019).

The impact of falls on balance confidence and fear of falling has been investigated in other populations. In elderly individuals and individuals with Parkinson's disease, those who had fallen in the past had significantly lower balance confidence scores, as measured by the ABC Scale, than those who had not fallen before (Lajoie & Gallagher, 2004; Mak & Pang, 2010). In individuals with dystonia, fear of falling scores as measured by the Falls Efficacy Scale International (FES-I), were high and ABC Scale scores were low and both worsened if there was a history of falls (Boyce et al., 2017). Additionally, Major (2019) reported the ABC Scale was associated with the likelihood of falling in individuals with ULL/D; however, other factors that may impact falls continue to be unknown.

Embodiment

The concept of embodiment is rooted in psychology which has recently been used in neuroscience to look at the relationship between people and their assistive device tool such as a prosthesis (Cardinali et al., 2009; Gouzien et al., 2017; Pazzaglia & Molinari, 2016). The term embodiment has been described as a specific type of information processing and the sense of embodiment includes the feeling of ownership (De Vignemont, 2011). Embodiment has often been described in relation to the rubber hand illusion (RHI). In the RHI, one of the individual's hands is hidden from view with a screen while a rubber or prosthetic hand is placed in front of them. The individual is instructed to stare at the artificial hand while both their hand and the artificial hand are brushed simultaneously (Botvinick & Cohen, 1998). This RHI causes the individual to sense the touch of the artificial hand instead of their own (Botvinick & Cohen, 1998). Longo, Schüür, Kammers, Tsakiris, and Haggard (2008) identified embodiment subcomponents in the RHI of ownership (feeling the rubber hand was part of their body), location (feeling their hand and the rubber hand were in the same spot), and agency (feeling they were able to move the rubber hand). When an individual uses a tool such as a prosthetic device, the ability to incorporate their physical body awareness with the device is necessary to interact with their environment. This connection between body perception and the tool is often called embodiment and could be one of the critical factors affecting functional recovery (Pazzaglia & Molinari, 2016).

Many studies combine a short questionnaire after the RHI to capture the individual's experience in an attempt to quantify embodiment. The Embodied Sense of Self Scale (ESS) is a questionnaire that was developed to measure disturbances to the sense of self, as seen in schizophrenia (Asai, Kanayama, Imaizumi, Koyama, & Kaganoi, 2016). However, some of the challenges with identifying subjective embodiment is that the feeling of self is a concept of which we are not always aware (Asai et al., 2016). Although these studies are just a few examples of the work that has been done in relation to embodiment using the RHI, the construct of embodiment including in relation to upper limb prosthesis users continues to be difficult to quantify.

Prosthesis embodiment in individuals with upper limb loss. Embodiment is a complex experience that ranges from self-embodiment to embodiment of rubber limbs, tools, and prostheses (Giummarra, Gibson, Georgiou-Karistianis, & Bradshaw, 2008). Prosthesis embodiment is explained as the process when individuals with limb loss view their device as an extension of themselves (Dornfeld et al., 2016). Although the term embodiment is not commonly used by prosthesis users or the rehabilitation team, the extent a prosthesis user integrates their prosthesis into their life (Gouzien et al., 2017) is commonly reviewed in the rehabilitation process and captures the sense of embodiment. Canzoneri, Marzolla, Amoresano, Verni, and Serino (2013) found that individuals with ULL/D, who were long-term prosthesis users, perceived their residual limb as longer and their peripersonal space with boundaries expanded to include the area around their prosthetic hand. However, those who did not wear their prosthesis perceived their residual limb as shorter and their peripersonal space around their residual limb shrank (Canzoneri et al., 2013). When wearing a prosthesis, the reaching space is smaller than it is with a healthy limb. Despite that, individuals judged they could reach as far with their prosthesis as they could with their healthy limb. Interestingly, this overestimation was smaller with the prosthesis than the sound limb when the individual had high prosthesis integration as measured by a questionnaire on how they used and experienced their prosthesis (Gouzien et al., 2017). Studies also suggest that long-term tool use, such as a mechanical grabber, can increase performance of using the prosthesis and lead to incorporating the tool into their body representation (Cardinali et al., 2009).

Murray (2004) found that although individuals with congenital limb absence did not have phantom limb sensation, they reported the sense of embodiment with their prosthesis. This study acknowledges that prosthesis users whether due to amputation or from congenital limb absence, often provide explanations of integrating the prosthesis into their body structures (Murray, 2008). Daily upper-limb prosthesis users who embodied their prosthesis (reported the prosthesis as part of themselves and an inability to perform tasks without it), reported reduced environmental obstacles such as climate, prosthesis inadequacies, and attitudes, while those who did not use their prosthesis daily did not experience prosthetic embodiment and reported challenges in these areas (Widehammar, Pettersson, Janeslätt, & Hermansson, 2017). Nico, Daprati, Rigal, Parsons, and Sirigu (2004), found that individuals who wear a more functional prosthesis (those that assist in task performance such as myoelectric or body-powered) versus aesthetic prosthesis (passive or cosmetic), may also have a greater sense of embodiment. These studies suggest that individuals who wear their functional prosthesis more frequently, have a sense of embodiment. However, it is unknown if these factors of prosthesis use and embodiment impact an individual's balance confidence, fear of falling, or fall likelihood.

Embodiment and balance. Body posture is maintained by utilizing information from visual, vestibular, and somatosensory systems (Collins & De Luca, 1993). Balance and body posture is maintained by combining a feedforward system, which anticipates the motor control needed (van der Kooij, Jacobs, Koopman, & Grootenboer, 1999), with a feedback system, where the intended location of a body part is compared with its actual location through information received from multiple sensory inputs (Mergner & Rosemeier, 1998). The body schema or representation of one's own position and movement body in space (Holmes & Spence, 2004), and incoming kinesthetic information are important factors for postural control (Gurfinkel, Ivanenko, Levik, & Babakova, 1995). Although individuals with ULL/D may lack some perceptual feedback due to their loss of limb, using a prosthesis to restore their body schema

(Mayer, Kudar, Bretz, & Tihanyi, 2008) may positively contribute to postural control (Imaizumi et al., 2016).

As previously mentioned, quantifying embodiment in individuals with ULL/D has mainly been reported in relation to the RHI. Embodiment subcomponents identified by Longo et al. (2008) are ownership, agency, and location. Ownership refers to the feeling that the artificial limb is part of their body, agency is the feeling of having control over the artificial limb and being able to move it, and location refers to the sense that the artificial hand and the individual's own hand were in the same space (Longo et al., 2008). It has been reported that agency can create body ownership towards external objects (Asai, 2016; Imaizumi et al., 2016). Imaizumi et al. (2016), found that frequent use of a prosthesis by individuals with ULL/D creates a greater sense of embodiment which is related to improved posture. On the other hand, infrequent use of a prosthesis led to a diminished sense of embodiment and increased postural sway or movement outside of the center of gravity. For individuals to have improved posture and embodiment and have a sense of agency rather than ownership, they need to willingly use and operate their prosthesis as well (Imaizumi et al., 2016). Although findings from Imaizumi and colleagues' (2016) study suggest individuals who report they have control over their prosthesis (agency) was more important than ownership in postural control, it should be interpreted with caution given the small sample size ($N = 9$). Also, the study results may not be transferred to all individuals with ULL/D (Imaizumi et al., 2016). This study provides insight into the importance of agency when characterizing prosthesis embodiment and its relationship to balance confidence and falls. From the evidence, it can be hypothesized that those who have a sense of agency may also report a feeling that their prosthesis is part of their body (ownership) which leads them to wear their prosthesis more and in turn, improved stability; however, this is currently unknown. Identifying how the frequency of prosthesis use and prosthesis embodiment affect balance confidence and falls can suggest appropriate evaluation and treatment methods to prevent potential injuries in this patient group. However, literature addressing the current research question of evaluating the relationship of prosthesis use and embodiment with balance confidence, fear of falling, and falls in persons with ULL/D is absent.

Method

Study Design

This was a cross-sectional study that assessed the associations and potential relationships between frequency of prosthesis use, embodiment, balance confidence, fear of falling, and falls among adults with ULL/D. Participants completed an anonymous online survey, using Qualtrics® (Provo, UT), an online survey platform, or completed the survey over the telephone. The survey was available to participants from September 2018 to December 2018. Prior to participant recruitment, the study was approved by the Institutional Review Board (IRB) for Social Behavioral Research from Northwestern University.

Participants

A convenience sample was recruited from several sites: the Amputee Coalition website, the Skills for Life Bilateral Upper Limb Loss Workshop, the Shirley Ryan AbilityLab Prosthetic and Orthotic Care Center (POCC), the Center for Bionic Medicine (CBM), the outpatient therapy center, the Shirley Ryan AbilityLab Amputee Registry, and the Northwestern University Prosthetics-Orthotics Center. In addition, snowball sampling strategy was used to identify additional participants. Participant eligibility criteria for inclusion into the study included English-speaking, at least 18 years of age, and having one or more ULL/D at the wrist level or higher.

Prior to the start of the study, an a priori minimum sample size estimation was conducted using G*Power, version 3.1 (Faul, Franz, Erdfelder, Buchner, & Lang, 2009). The sample size calculation was based on a two-tailed correlation bivariate normal model between prosthesis use and balance confidence. The effect size was based on results from the study by Major (2019) which reported a correlation of .35 between prosthesis use (years) and the ABC. In addition, the following parameters were used, α of .05, β of .20. From this calculation, it was estimated a minimum sample size of 61 participants was needed to sufficiently power the study. Additional participants were recruited to increase statistical power of the study.

Data

The survey (Appendix A) consisted of the consent document and four separate instruments and/or questionnaires: sociodemographic and participant characteristic questionnaire, the ABC Scale instrument (Appendix B), the Falls Efficacy Scale – International (FES-I) instrument (Appendix C), and an embodiment questionnaire (Appendix D). Sociodemographic and patient characteristic data included: age, gender, time since limb loss, level of limb loss, cause of limb loss, prosthesis type and usage, comorbidities, medications, and fall history. While it was expected that most participants would complete the survey online, participants were given the option of having the data collected by the primary researcher (K. T.) in person or over the telephone. Once the survey was closed, data were downloaded into an Excel spreadsheet, checked for errors, and formatted for data analysis. Once this was completed, the data were exported into IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY) for analysis.

Operationalization of variables. Balance confidence was measured with the ABC Scale and fear of the falling was measured with the FES-I. Age and time since limb loss/difference were measured in years. The most proximal level of limb loss reported (at or through the shoulder, between the shoulder and elbow, at the elbow, between the elbow and wrist, at wrist, and part of the hand) and prosthesis type (passive/cosmetic, body-powered, myoelectric/motorized, activity-specific, or hybrid) for this level was used, therefore only the most proximal side was included for participants with bilateral ULL/D. Individuals who reported having bilateral ULL/D at the wrist or proximal on one side and the level of partial hand on the other side were included in the bilateral ULL/D category, although only the proximal side was used for limb loss level. Categories for the cause of limb loss/difference included trauma/accident, congenital, infection, cancer, and other with the option of filling in a category not listed. Prosthesis use was determined by the number of days per week the individual reported wearing their prosthesis multiplied by the number of hours a day they reported wearing their prosthesis, giving a total number of hours of use in a week. Comorbidities were measured using the Functional Comorbidity Index (FCI). A medication was defined as something prescribed by a physician and a fall was defined as coming to rest accidentally on the ground or other lower level, other than because of lost consciousness, a violent blow, stroke, or epileptic seizure (Askham et al., 1990). Consistent with the study by Major (2019), frequent fallers were defined as reporting two or more falls and non-fallers as reporting up to one fall, to capture where falls may be a fundamental problem.

Instruments

The following instruments were incorporated into the survey which was completed by all study participants. Permission to use these surveys was granted by the instrument authors.

Activities-Specific Balance Confidence Scale. The ABC Scale (Appendix A) is a self-report measure in which individuals rate a variety of activities on a scale of 0 to 100 by how confident they are performing each listed activity without falling. A score of zero represents no confidence and a score of 100 represents complete confidence. An overall score is calculated by summing the individual scores for each of the 16 items and then dividing by 16, the total number of items on the scale. The final score is reported as a percent of balance confidence. The ABC Scale has been utilized with other populations including individuals with Parkinson's disease, stroke, and multiple sclerosis, older adults, and LL amputation. In individuals with LL amputation, the ABC Scale has excellent test-retest reliability (ICC = .91) and internal consistency, Cronbach's α =.95 (Miller, Deathe, & Speechley, 2003). Convergent validity was demonstrated with a positive association, r = .72, 95% CI [0.56, 0.84] with the 2 Minute Walk Test and a negative association, r = -.70, 95% CI [-0.82, 0.53] with the Timed Up and Go (Miller et al., 2003). Although the ABC Scale has not been validated for those with ULL/D, both individuals with UL and LL loss have reported similar balance confidence and evidence suggests ABC Scale scores are related to falls in those with LL amputation (Wong, Chen, Blackwell, Rahal, & Benoy, 2015). Evidence also suggests ABC Scale scores are related to falls in other populations with unsteadiness such as multiple sclerosis (Tajali et al., 2017), Parkinson disease (Mak & Pang, 2009), dystonia (Boyce et al., 2017a), and community-dwelling elderly (Lajoie & Gallagher, 2004a). This may better explain the factors influencing fall risk among those with ULL/D.

Falls Efficacy Scale – International. The FES-I (Appendix B) is a self-report measure in which individuals rate 16 functional activities on a four-point Likert scale on how concerned they are that they might fall. A score of one means they are not at all concerned and a score of four means they are very concerned. Scores for each question are added together to calculate a total score, with a higher score signifying a greater fear of falling. The FES-I was developed to measure older adults with or without a history of fear of falling. During initial validation and development of the scale, it showed excellent internal and test-retest reliability (Cronbach's α = .96, ICC = .96, respectively) in community-dwelling older adults (Yardley et al., 2005). The FES-I has excellent test-retest reliability with individuals with vestibular disorders (ICC = .94) and criterion validity with ABC Scale scores (r = -.84) (Morgan, Friscia, Whitney, Furman, & Sparto, 2013). Similar to the ABC Scale, evidence suggests the FES-I has been able to accurately predict falls in individuals with multiple sclerosis (Mazumder, Murchison, Bourdette, & Cameron, 2014). Although the FES-I has not been validated for those with ULL/D, examining the fear of falling may better explain the factors influencing fall risk among these individuals.

Embodiment questionnaire. The custom-designed embodiment questionnaire (Appendix C) measured self-reported prosthetic embodiment. It consists of Likert-like scale questions which are based on a review of the literature and a questionnaire created by Imaizumi, Asai, and Koyama (2016) and a variation of Gouzien et al. (2017). There were a total of 12 questions, but individuals with bilateral ULL/D did not complete questions 2, 8, and 9 as these questions required indicating towards intact side or side of ULL/D. A high score indicated more embodiment with their prosthesis and a lower score indicated less embodiment. To establish face validity of the questionnaire, it was assessed by other experts in the field of embodiment with ULL/ as well as by Imaizumi, the lead author of the Imaziumi et al. (2016) article. Revisions and additions were made based on feedback from occupational therapists, rehabilitation scientists, prosthetists, and biomedical engineers. All agreed the measure had adequate face validity. This is a newly created questionnaire; therefore, validity and reliability have not been fully evaluated. However, during the current study, the internal reliability of the questions was assessed using a Cronbach's alpha. For this study, a Cronbach's alpha of .70 was considered acceptable. This cutoff value was based on what is reported literature (Nunnaly, 1978; George & Mallery, 2003). The Cronbach's alpha reliability coefficient for individuals with unilateral ULL/D was $\alpha = .83$ and for those with bilateral ULL/D was $\alpha = .81$. Both these values are considered good and are above the acceptable cutoff value (George & Mallery, 2003).

Functional Comorbidity Index. The FCI is an 18-item list of diagnoses that can be used in the general population to determine physical function. Individuals answer "yes" or "no" to whether they have the diagnoses listed. The score is determined by adding "yes" answers, with zero meaning no comorbid illness up to 18 meaning the highest number of comorbid illnesses. Understanding the effects comorbidities may impact the physical function of individuals with ULL/D can assist in determining fall risk, therefore the FCI was chosen. The FCI is a better indication of physical function compared to the Charlson Comorbidity Index and the Kaplan-Feinstein Index and explained more variance in physical function than these measures that are used to predict mortality (Groll, To, Bombardier, & Wright, 2005). In patients undergoing orthopedic surgery, the FCI predicted the occurrence of all adverse events and was consistently stronger in this association than the Charlson Comorbidity Index (Gagnier, Morgenstern, & Kellam, 2017). The information from the FCI in addition to the other measures utilized in this study may provide important information in evaluating individuals with ULL/D safety.

Procedures

Recruitment. Participants were identified through the Amputee Coalition website and the Skills for Life Bilateral Upper Limb Loss Workshop, Shirley Ryan AbilityLab POCC, the CBM, the outpatient therapy center, and the Shirley Ryan AbilityLab Amputee Research Registry. Participants who met inclusion criteria as stated above were recruited to participate in the study.

The Amputee Coalition website. The Amputee Coalition is the nation's leading organization on limb loss and limb difference and provides education, support, and advocacy. They are committed to preventing limb loss, improving patient care, and increasing the quality of life for individuals with limb loss and limb difference and their families. Once approval was given by this organization, study information was posted to their respective social media pages including their website and Facebook page.

Skills for Life Bilateral Upper Workshop. Upon approval from the conference committee, participant recruitment and data collection were done at the national conference called the Skills for Life Bilateral Upper Limb Loss Workshop which was held in Houston, Texas in October 2018. This conference was for individuals with bilateral ULL/D and individuals with multiple limb loss, their families as well as clinicians, vendors, and researchers. In addition, study information was posted on their Facebook page.

Potential participants were identified at the conference by the primary researcher or by trained clinicians. Individuals with ULL/D were approached by the primary researcher or a trained clinician to determine if they were interested in participating in the survey. If they were interested, they were given a computer or tablet to complete the consent and survey either independently or the primary researcher read the consent verbatim and recorded the participant's responses. If the individual was interested in participating in the study but was unable to complete the survey at that time, a flyer was provided with the link to the study. Individuals could access the survey from home and complete the consent form and survey on their own computer. Permission for the researcher to recruit at this conference was given once IRB approval was obtained.

Northwestern University Prosthetics-Orthotics Center. Individuals with ULL/D who served as patient models as part of the clinical education program were contacted by the primary researcher. Individuals interested in participating in the study were emailed the link to the survey. If the participant preferred to participate in the study over the phone, the primary researcher scheduled a telephone meeting for obtaining consent and data collection.

Shirley Ryan AbilityLab Prosthetic and Orthotic Care Center and the outpatient therapy center. Individuals were identified by clinicians in the POCC and outpatient centers. The researcher educated colleagues in the POCC and the outpatient center about the study and requested recruitment of their own clients who fit the inclusion criteria. Recruitment materials were provided to clinicians in the POCC and the outpatient clinic at the Shirley Ryan AbilityLab. These materials consisted of a flyer that was emailed or printed out that provided information about the purpose of the study, participation requirements, risks and benefits of this study, a link the participant could go to for completing the consent and survey for the study, and researcher contact information for study inquiries or concerns. Interested participants were able to utilize the link provided for consent and completing the study or could contact the primary researcher directly via the contact email or phone number provided via the recruitment flyer. A follow-up phone call or meeting could be made with the researcher to discuss the study protocol if desired by the participant.

Shirley Ryan AbilityLab Center for Bionic Medicine. Potential participants who fit the inclusion criteria of having ULL/D were also be identified by the primary researcher if they have been involved in prior research studies with CBM by following up by phone or email. Interested participants could utilize the link provided for consent and completing the study or could contact the researcher directly via the contact email or phone number provided via the recruitment flyer. A follow-up phone call or meeting could be made with the researcher to discuss the study protocol if desired by the participant.

Amputee Research Registry. The research registry is an IRB approved list of individuals who have been consented to be contacted for future research studies. Permission for the primary researcher to use the registry was given after the IRB approved the proposed study. Once IRB approval was obtained, individuals with ULL/D were contacted by the primary researcher via telephone or email to invite them to participate in the study. Individuals interested in participating in the study were emailed the link to the survey. If the participant preferred to participate in the study over the phone, the primary researcher scheduled a telephone meeting for obtaining consent and data collection.

Informed consent. Informed consent was obtained through the online survey or verbally by the primary researcher. The informed consent document was on the first page of the survey. To be able to progress to the survey, participants had to indicate they read the informed consent document and agreed to participate in the study. For those who took the survey over the phone, the primary researcher read the consent verbatim and recorded the participants' responses. Potential participants were exclude if they did not agree to the terms of the consent. If the participant agreed to the terms of the consent, the researcher continued to the survey questions.

Survey procedure. Surveys were completed either online independently or researcher guided in-person or via the telephone. Individuals interested in participating in the study were given a flyer or sent an email that contained a link to the survey. The researcher guided option was provided to allow individuals who did not have access to a computer the opportunity to participate in the study. Research has shown that using different modes of data collection does not negatively impact the quality of the data collected (Revilla, 2012). Surveys completed in-person or over the phone were entered into the Qualtrics® program by the primary researcher at the time the survey was completed. Each question was read verbatim as it appeared in the survey to ensure accuracy. If questions arose, further clarification was provided by the primary researcher via telephone or at the time the participant was completing the survey if the primary researcher was present. The entire process of consenting and completing the survey took between 15-20 minutes.

Confidentiality. Survey participants were anonymous and no personally identifying or sensitive information was obtained from participants. All data collected from participants were considered privileged and held in confidence. Study data are stored in password-protected computers or in locked filing cabinets as applicable. In the case that study results are published, given no personal identifying data was collected, participants' identities will not be indicated. The data will be destroyed after seven years or later when it is deemed no longer scientifically relevant.

Statistical Analysis

All data analysis was conducted using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY). All comparisons were two-tailed and an alpha level less than .05 was considered statistically significant. Data assumptions of normality were tested on the following variables: frequency of prosthesis use, embodiment, the ABC Scale, and the FES-I utilizing the Shapiro-Wilk test and skewness/kurtosis. Prosthesis use ($p < .001$), the ABC Scale ($p < .001$), and the FES-I ($p < .001$) were not normally distributed. Embodiment scores in both individuals with unilateral ULL/D ($p = .648$) and individuals with bilateral ULL/D ($p = .458$) were normally distributed. Non-normally distributed data are reported as median and 25th and 75th percentiles. Normally distributed data are reported as mean and standard deviation. Although embodiment scores in individuals with unilateral ULL/D and in individuals with bilateral ULL/D were normally distributed, the continuous dependent variables used for the correlation tests were not normally distributed therefore, the non-parametric Spearman rho correlation coefficient was used. Correlation coefficient (r) strength was interpreted as follows: $r < .30$ very weak correlation or none; $.30 < r < .50$ weak correlation; $.50 < r < .70$ moderate correlation; and $r > .70$ strong correlation (Moore, Notz, & Flinger, 2013).

The same variables (frequency of prosthesis use, ABC Scale, FES-I, embodiment score) were tested for normality using the Shapiro-Wilk test *p* values and skewness/kurtosis looking at the difference between fallers and non-fallers. Frequency of prosthesis use with non-fallers ($p = .001$) was not normally distributed; however, frequent fallers ($p = .068$) were normally distributed. There was not normal distribution with the ABC Scale in frequent fallers ($p = .001$), or non-fallers ($p < .001$) or with the FES- I in the non-fallers group ($p < .001$). However, in the frequent faller group, there was normal distribution ($p = .052$). Because the data were not normally distributed in both groups within each of the variables, the non-parametric Mann-Whitney *U* test was used to look for differences between groups. Effect sizes were calculated and interpreted using Cohen's *d* indicating a small effect size of .20, a medium effect size of .50, and a large effect size of .80 (Cohen, 1992).

Results

A total of 97 participants started the survey; however, only 84 (86.6%) completed the survey and were included in the analysis. Detailed characteristics of the 84 participants can be found in Table 1. For the overall sample, the median age of participants was 50.50 years, the majority were male, had unilateral ULL/D between the elbow and wrist caused by trauma.

Primary Hypotheses

Prosthesis use and balance confidence. The null hypothesis was tested that there will not be a relationship between frequency of prosthesis use and balance confidence. The alternative hypothesis was that there will be a statistically significant relationship between prosthesis use and balance confidence. Based on a Spearman rho correlation, as can be found in Table 2, a very weak positive non-significant correlation was found between frequency of prosthesis use and ABC Scale scores. The null hypothesis was accepted.

Prosthesis use and fear of falling. The null hypothesis that there will not be a relationship between frequency of prosthesis use and fear of falling was tested. The alternative hypothesis was that there will be a statistically significant relationship between prosthesis use and fear of falling. Based on a Spearman rho correlation, as can be seen in Table 2, a very weak positive non-significant correlation was found between frequency of prosthesis use and FES-I scores. Therefore, the null hypothesis was accepted.

Prosthesis use and incidence of falls. The null hypothesis was tested that there will not be a relationship between prosthesis use and incidence of falls (fallers and non-fallers) and the alternative hypothesis was that there will be a relationship between prosthesis use and incidence of falls. As can be seen in Table 4, results indicate there was not a statistically significantly difference in prosthesis use by incidence of falls; however, there was a medium effect size. The null hypothesis was accepted.

Prosthesis use and embodiment. The null hypothesis was that there will not be a relationship between frequency of prosthesis use and embodiment. The alternative hypothesis was that there will be a statistically significant relationship between frequency of prosthesis use and embodiment. As can be seen in Table 2, there was a medium positive significant correlation between frequency of prosthesis use and embodiment scores in individuals with unilateral ULL/D while a strong positive correlation was found between frequency of prosthesis use and embodiment scores in individuals with bilateral ULL/D. Results suggest as prosthesis use increases, embodiment scores also increase in both individuals with unilateral ULL/D and individuals with bilateral ULL/D. The null hypothesis was rejected and the alternative was accepted.

Embodiment and balance confidence. The null hypothesis tested was that there will not be a relationship between prosthesis embodiment scores and balance confidence and the alternative hypothesis was that there will be a relationship between prosthesis embodiment scores and balance confidence. A very weak positive non-significant relationship was found between embodiment scores of individuals with unilateral ULL/D and ABC Scale scores and embodiment scores of individuals with bilateral ULL/D and ABC Scale scores. See Table 3 for the details. The null hypothesis was accepted.

Embodiment and fear of falling. The null hypothesis that there will not be a relationship between prosthesis embodiment and fear of falling and the alternative hypothesis that there will be a relationship between prosthesis embodiment and fear of falling was tested. A very weak negative non-significant relationship was found between embodiment and fear of falling for both individuals with unilateral and bilateral ULL/D. Therefore, the null hypothesis was accepted. Detailed results can be found in Table 3.

Embodiment and incidence of falls. The null hypothesis that there will not be a relationship between embodiment between and incidence of falls and the alternative hypothesis was that there will be a relationship between embodiment and incidence of falls was tested. As can be seen in Table 4, results indicate there was not a statistically significant difference in embodiment by incidence of falls for individuals with unilateral ULL/D or bilateral ULL/D. For unilateral ULL/D there was a small effect size while there was a medium effect size for individuals with bilateral ULL/D. The null hypothesis was accepted that there was not a statistically significant difference in embodiment by incidence of falls.

Secondary Hypotheses

Difference between balance confidence and incidence of falls. The secondary hypothesis was tested that there will not be a difference between balance confidence and incidence of fall; the alternative hypothesis was that there will not be a difference between balance confidence and incidence of fall. Results (see Table 4) indicate there was a statistically significant difference in balance confidence by incidence of falls with non-fallers having greater confidence. A medium high effect size was also found. The null hypothesis was rejected and the alternative was accepted.

Difference between fear of falling and incidence of falls. The secondary hypothesis that there will not be a difference in fear of falling by incidence of fall. The alternative hypothesis was that there will not be a difference in fear of falling by incidence of falls. There was a statistically significant difference in fear of falling by incidence of falls with non-fallers having a lower fear of falling compared to frequent fallers. There was also a large effect size. The null hypothesis was rejected and the alternative is accepted.

Discussion

The purpose of this study was to evaluate the relationship between the frequency of prosthesis use and embodiment with balance confidence, fear of falling, and falls in persons with ULL/D. Participant characteristics of this study align with previously published studies on this population. In the current study, the majority of participants were men (69%) with ULL/D due to trauma (54.8%) which is consistent with previous studies in which researchers reported males were more likely than women to have ULL/D from trauma (Dillingham, Pezzin, & MacKenzie, 2002; Varma, Stineman, & Dillingham, 2014). Study participants' median age of 51 years for this study was similar to mean age of 43 years reported by Major (2019). Frequent fallers of the total sample made up a larger proportion of the total participants at approximately 40.1% compared to Major (2019), who had 28.6%. This may be explained by the fact that the current study also had a larger number of individuals with bilateral ULL/D, (n = 24, 28.6% of the total sample) compared to 16 individuals, 16.3% of the total sample, in the study by Major (2019). Of the individuals with bilateral ULL/D of the total sample, 45.8% had frequent falls and those with unilateral ULL/D, 38.3% had frequent falls. Because individuals with bilateral ULL/D had a higher percentage of frequent fallers than those with unilateral ULL/D, this may also explain why this study had more frequent fallers. Another explanation as to why there are more frequent fallers in this study is that Major's study also had a larger number of individuals with congenital ULL/D, (n = 47, 48.0%) compared to this study (n = 12, 14.3%). In addition, the current study had more individuals with ULL/D due to trauma, n = 46 (54.8%), higher than the study by Major (2019), n = 42 (42.9%). It is possible that individuals who were born with a limb deficiency have adapted how they perform tasks to their living environment and falling may not be as much of a concern. Those who have acquired limb loss may not have had fully adapted to their environment. This is especially true for individuals as they are learning how to utilize their prosthesis where lateral and forward trunk flexion are commonly needed to position the prosthesis for functional tasks (Metzger, Dromerick, Holley, & Lum, 2012). These movements may create a change in their center of gravity causing them to lose their balance and potentially sustain a fall. However, the study by Major (2019) did not find etiology to be associated with frequent falls, so there is some doubt that this is the reason for the increase of frequent fallers in the current study. Additionally, the study by Major (2019) only involved online recruitment and the current study involved online and in-person (rehabilitation center, research center, and a conference). Because the primary researcher works with individuals with ULL/D and knew some of the participants, in-person recruitment may have influenced participants' responses. Although the researcher read and reported the survey questions verbatim, participants may have reported falls with the anticipation that the researcher was looking for individuals who had experienced a fall in order to please the researcher.

Primary Hypotheses

Prosthesis use. There was not a significant relationship found between frequency hours of prosthesis use and the ABC Scale and the FES-I. Therefore, the null that there will not be a relationship between frequency of prosthesis use and balance confidence and the null that there will not be a relationship between frequency of prosthesis use and fear of falling were accepted. This indicates that neither balance confidence (ABC Scale scores) or fear of falling (FES-I) are associated with the frequency amount of time an individual wears a prosthesis. The FES-I was developed to improve the ability to assess fear of falling in more demanding social and physical activities as compared to the FES and was better at detecting differences in those who have fallen before and fall risk factors (Yardley et al., 2005). The ABC Scale was developed to also assess fear of falling, but with more difficult activities and more detail than the FES (Powell & Myers, 1995). Although similar measures, the ABC Scale asks about confidence in becoming unsteady or losing balance which assumes that balance can be recovered, whereas the FES-I specifically asks about the concern for falling. This study had a majority of individuals who have ULL/D due to trauma and are younger which is consistent with the literature (Ziegler-Graham, MacKenzie, Ephraim, Travison, & Brookmeyer, 2008). Although both the ABC Scale and FES-I ask about a variety of activities, younger individuals may participate in activities that put them at risk for falling which was found in another study (Wong, Chihuri, & Li, 2016). If younger individuals with ULL/D do participate in risker activities, they may perceive themselves as being a confident person and not intimidated challenges. This may lead them report balance confidence and very little fear of falling. Additionally, low balance confidence and fear of falling are seen when there has been a fall in the past (Boyce et al., 2017b; Lajoie & Gallagher, 2004b; Mak & Pang, 2010). If an individual has not fallen recently, he or she may not report low balance confidence or fear of falling. It is also possible that prosthesis use may not impact ABC Scale and FES-I scores. Biddiss and Chau (2007) reported many individuals wear their prosthesis passively and Ostlie et al. (2012) reported many only wear them half of the time in everyday life and have adjusted their activities accordingly. Therefore, individuals may feel confident they will not become unsteady and will not have a fall. Another possibility a significant relationship was not seen between frequency of prosthesis use and balance confidence and fear of falling is that both the ABC Scale and the FES-I responses showed a ceiling/floor effect. Many of the respondents were at the highest confidence level on the ABC Scale and lowest scores for fear of falling for the FES-I, causing little variability, which questions the ability of these measures to detect any change. This lack of variability in these measures could be one factor no significant relationship was found. It also cannot be ruled out that these results may also indicate that there is not a relationship between frequency of prosthesis use and self-reported balance confidence, and hours of prosthesis use and self-reported concern of falling because there are other factors that were not considered in the study.

A moderate positive significant relationship was between the frequency of prosthesis use and embodiment scores of individuals with unilateral ULL/D and bilateral ULL/D. These results are similar to those reported by Imaizumi et al. (2016); individuals who wore their prosthesis more often reported more embodiment. To make a prosthetic device or tool useful to the user, the device must be worn to gain experience and skill in using the device. If a prosthetic device feels like an extension of themselves, it makes sense that the individual would wear it more. This aligns with previous findings that individuals who wore their prosthesis frequently felt prosthesis embodiment and those who were infrequent prosthesis users did not (Widehammar, Pettersson, Janeslätt, & Hermansson, 2017). Although this study and previous findings suggest there may be a relationship of prosthesis embodiment and frequency of prosthesis use, the construct of embodiment continues to be a complex one and it is likely multiple factors influence prosthesis embodiment. Further investigation into the ability of the embodiment questions utilized in this survey to accurately identify prosthesis embodiment is needed as the connection between body perception and the prosthesis (embodiment) could be one of the critical factors affecting functional recovery (Pazzaglia & Molinari, 2016).

Embodiment. Both the null hypothesis that there would not be a relationship between prosthesis embodiment scores and the ABC Scale (balance confidence) and that there will not be a relationship between prosthesis embodiment scores and the FES-I (fear of falling) was accepted. No significant relationships were found in individuals with unilateral ULL/D or bilateral ULL/D in embodiment scores and the ABC Scale scores or FES-I scores. These results suggest that embodiment level of a prosthesis does not impact individuals' subjective balance confidence or fear of falling. Although individuals with ULL/D may lack some perceptual feedback due to their loss of limb, using a prosthesis to restore their body schema (Mayer, Kudar, Bretz, & Tihanyi, 2008) may positively contribute to postural control (Imaizumi et al., 2016). However, for individuals to have improved posture and embodiment, they need to willingly use and operate their prosthesis willingly use and operate their prosthesis as well as have a sense of agency (control over their prosthesis) rather than ownership (Imaizumi et al., 2016). Therefore, even though there was a relationship between frequency of prosthesis use and embodiment, the sense of agency rather than ownership could be missing as agency was only asked on three of the questions. If an individual does not feel he or she has control over the prosthesis, the frequency of use may not affect balance confidence or fear of falling, which may explain why there was no relationship found. The limited variability in ABC Scale and FES-I scores as mentioned previously could be another possible explanation of why they were not associated with embodiment scores.

Frequent fallers and non-fallers. For both the null hypotheses, that there was no observed difference between frequency of prosthesis use in individuals with unilateral or bilateral ULL/D who reported frequent falls or were non-fallers and that there will not be a difference in embodiment between self-reported fallers and non-fallers; were accepted. Despite that there was no statistical difference found with prosthesis use between fallers and non-fallers, the statistical difference found ($p = .055$) could be considered marginally significant and there was a medium effect size ($d = 0.43$). The effect size is an indirect way of measuring clinical significance and indicates that prosthesis use was different between frequent fallers and non-fallers and is supported by the marginally significant results. Had the sample size been larger, there may have been enough power to show a statistical significance between the groups.

This marginally significant difference and medium effect size found makes can also be supported clinically. Besides the compensatory movements required to operate a prosthesis, the mechanics of a prosthesis are not the same as a sound arm and are not able to create the appropriate actions to stop a fall. This may be further supported by the summary characteristics of the frequent faller group that showed they reported using their prosthesis more. Therefore, wearing a prosthesis more often may put these users at an increased risk of being in a situation where they might try to use the device to avoid a fall. This may also indicate why there were differences in the frequency of prosthesis use between the frequent fallers group and the non-fallers group. Because the significance was marginal and there was a medium effect size, future work to further investigate the impact prosthesis use may have on individuals with ULL/D and the potential of falls is warranted.

It is known that individuals who use upper limb prostheses do not use their devices consistently throughout the day and may have multiple devices they use. Individuals reported wearing a prosthesis (80%) of the time, but only about half wore them in everyday life (Ostlie et al., 2012). This coincides with the fact that activities of daily living are often the most challenging to perform with a prosthesis (Datta, Selvarajah, & Davey, 2004) and that many wear their prosthesis passively (Biddiss & Chau, 2007). This is also in agreement with a study that looked at the correlation between electronically tracked usage data (minutes prosthesis was turned on and motors in use) of myoelectric users and self-reported prosthesis use. Researchers found that over an eight-week period participants reported wearing their prosthesis an average of two hours per day but actual prosthesis usage was only 7% of the time or 12-14 hours for the entire eight-week period (Simon, Turner, Miller, Hargrove, & Kuiken, 2019). Although this study was only myoelectric hand prosthesis users, it reflects real-time usage of prosthetic users while at home. The large amount of prosthesis time reported in the present study (49.5 hours per week), suggests that individuals likely reported overall wear time of the prosthesis rather than the actual use of the prosthesis. It is unknown if actual use instead of wear time could impact whether an individual would fall or not, however, because usage time is less than wear time, actual use time may not have an impact. Despite this, embodiment requires the use and operation of a prosthesis as well as have a sense of agency rather than ownership (Imaizumi et al., 2016); therefore, accurate frequency of use time of the prosthesis cannot be ruled out as a possibility to make an impact in both prosthesis use and embodiment in fallers and non-fallers. Although there was no statistical difference seen between prosthesis embodiment in individuals with unilateral ULL/D and individuals with bilateral ULL/D between frequent fallers and non-fallers, there was a medium effect size (d = 0.47) with individuals with bilateral ULL/D embodiment scores. This indicates that a difference was seen between the groups and with a larger sample size, there may not have been enough power to show a statistical difference. This also further indicates the need to further investigate the relationship prosthesis embodiment has on falls.

Secondary Hypotheses. The secondary null hypothesis that there will not be a difference in balance confidence between self-reported fallers and non-fallers was rejected. There was a significant difference between non-fallers and frequent fallers in ABC Scale scores indicating that fallers had lower balance confidence scores. These results agree with findings by Major (2019) suggesting that lower ABC Scale scores were associated with frequent falls. Additionally, the ABC Scale has been shown to accurately identify fall risk in a variety of other populations, including older adults (Lajoie & Gallagher, 2004b; Landers, Oscar, Sasaoka, & Vaughn, 2016), Parkinson's disease (Mak and Pang, 2009), and lower limb amputation (Miller, Deathe, & Speechley, 2003; Wong et al., 2015) and is utilized clinically for these groups. This further indicates that the ABC Scale may be a good measurement tool for individuals with ULL/D to predict future falls. Due to the ceiling effect seen in the present study, it is reasonable to further investigate the use of the instrument with this population.

The null secondary hypothesis that there will not be a difference in fear of falling between self-reported fallers and non-fallers was rejected. Statistically significant differences between frequent fallers and non-fallers in FES-I scores indicated that fallers have a higher fear of falling. This measure has been validated with other diagnoses such as multiple sclerosis (Van Vliet, Hoang, Lord, Gandevia, & Delbaere, 2013) as well as in older adults cross-culturally (Kempen et al., 2007). The ability of the FES-I to be able to identify fear of falling in individuals with ULL/D may indicate this population also experiences avoidance behavior from fear of falling. This is important since fear of falling as measured with the FES-I has been found to be a strong predictor of future falls in older adults (Landers et al., 2016). However, due to the floor effect seen in the present study, it is reasonable to further investigate the use of the instrument with this population.

Limitations

Limitations of this study may include recall bias, the embodiment questions, and the embodiment construct. Participants were asked about retrospective falls in the past 12 months so there is the risk of recall bias, which could have led to underreporting of falls. Although collecting self-reported fall history is less accurate than prospective monitoring of falls, in studies of older community-dwelling adults, recall of falls in the past 12 months had high specificity compared to collecting prospective fall data (Ganz, Higashi, & Rubenstein, 2005). As mentioned previously the embodiment questionnaire has not been validated so this may indicate that the questions asked do not truly capture self-reported embodiment or the construct of embodiment is more complex than what can be measured in a question format. However, there was high internal consistency among the embodiment questions so it may be that embodiment does not indicate whether someone with unilateral or bilateral ULL/D will fall or not.

Other possible limitations are the length of the survey, prosthesis use definition, and a bias to fallers. The survey length may have been a factor causing some participants (13.4%) to not complete the entire survey. However, the survey only took participants an average of 20 minutes to complete, was broken up into sections with an easy format to follow. To confirm this, the format of the survey, questions included, and length of time to complete was pilot tested by various clinicians, engineers, and individuals with ULL/D. The authors chose to measure prosthesis use as number of hours per day the participant wore their prosthesis, however we recognize that years of use and time since limb loss may have also been contributing factors to prosthesis use. In addition, as stated previously, ensuring an accurate understanding of prosthetic use versus prosthetic wear may not be truly captured in this survey format and may have not shown true relationships that may exist between frequency of prosthesis use and embodiment on falling. There is a possibility that the cohort in this study was biased to fallers or those with balance concerns due to the nature of the study and the way it was advertised. The purpose of the study was stated with the intention to better understand the impact of ULL/D on falls. Clinicians also may have chosen their clients who they knew specifically have fallen. In addition, one of the recruitment locations was at a conference specifically for individuals with bilateral ULL/D and a large number of individuals with multiple limb loss also in attendance, which may be biased to frequent fallers. Frequent fallers were higher in this study compared to previously reported by

Major (2019), which may have been due to clinicians choosing individuals with a history of frequent falls and increased number of participants with multiple limb loss which may lead to a higher number of falls. However, the other recruitment locations included all individuals with ULL/D without bias to one specific group.

Clinical Significance

The potential for the ABC Scale and the FES-I to be used clinically with individuals with ULL/D is a significant strength of the study. These measures each have only 16 questions and take a small amount of time to complete (5-10 minutes each), making them easy to integrate into a clinical environment. Because we recruited from a diverse population of individuals, including individuals with bilateral ULL/D and multiple limb loss, these outcome measurements may be more broadly applied to predict fall risk.

Although the term embodiment is not a term used clinically, clinicians refer to this relationship by investigating the usefulness of a prosthesis to an individual. If an individual feels that a prosthesis is an extension of themselves, the psychological impact cannot be understated. Individuals often report the feeling of a prosthesis making them whole or complete. These feelings may also reinforce a positive body image and give the user confidence to participate in the activities that are meaningful to them, which is a cornerstone of rehabilitation and enhances quality of life. In fact, Rybarczyk and Bahel, (2008) found that those with poor body image have been shown to suffer from negative outcomes such as decreased life satisfaction, quality of life, increased depression, and overall psychological adjustment. This strengthens the importance of body image and the major impact ULL/D can have on self-concept and body image as arms and hands are essential in daily activities (Rybarczyk & Bahel, 2008).

The relationship between prosthesis use and embodiment is an important connection to explore not only from the potential psychosocial impact but also on functional recovery. Gouzien et al. (2017), found that individuals who wore their prosthesis more because of these same feelings of completeness were also more aware of the limitations of the prosthesis and used it accordingly. Understanding the limitations of their prosthesis may cause individuals to adjust their activities accordingly and lessen their potential for a fall. This is particularly important as 31.7% of the individuals with ULL/D who reported falls, 14.6% required medical attention (Major, 2019). Therefore, it is necessary to obtain a greater knowledge of the potential relationships between prosthesis use and embodiment and how these may impact the functional recovery, fall incidence and overall well-being of individuals with ULL/D.

Future Work

Although there was high internal consistency with the embodiment questions, a more careful analysis of each question is needed to evaluate its ability to capture embodiment. If trends are able to be identified to determine if some questions were better than others at capturing embodiment, further modifications may be warranted. In addition, future validation of the measure is needed for the potential to be utilized in the clinical environment. If a therapist can utilize a questionnaire to capture prosthesis embodiment, this can assist in the evaluation of functional recovery and potentially fall incidence. Because the construct of embodiment is still largely unknown, further exploration utilizing these questions in combination with other methods of measuring embodiment would be beneficial.

This study also justifies the need for further evaluation to determine the validity and reliability as well as the potential of the ABC Scale and the FES-I to be used with this population in the clinical setting. Further exploration into each question individually to look for trends that may further indicate what specific areas individuals with ULL/D may find most challenging and could provide insight on potential treatment strategies. In addition to psychometric evaluation of the ABC Scale and the FES-I as tools to be used with this population, understanding if higher balance confidence or lower fear of falling reduces the likelihood of a fall or if not falling causes the higher balance confidence and reduced fear of falling.

Although it may be assumed that individuals with bilateral ULL/D or individuals with multiple limb loss may fall more, no studies currently evaluate this. Therefore, further exploration into these specific populations could assist with identifying specific fall prevention treatment programs if warranted. In addition, further investigation into these populations within this study is warranted to determine if this biased the results in the current study. Other future work to understand whether general prosthesis use or more details about the frequency of prosthesis use or other constructs such as type of prosthesis or actual usage may impact balance confidence, fear of falling, and the likelihood of falls. These results suggest that the relationship between prosthesis use and falls warrants some further exploration.

As occupational therapists are the primary therapy professionals that work with individuals with ULL/D, further investigation into those services may assist in overall functional recovery. Exploration on whether individuals received therapy on how to effectively use their device in their daily routine may not only affect prosthesis use and embodiment but balance confidence, fear of falling, and falls. This could assist therapists in identifying potential areas that may require more attention in therapy especially if safety due to potential falls is a concern. Finally, there are numerous other variables that can be explored that may help further understand the relationships discussed in this study as the area of fall risk with individuals with ULL/D is largely unknown. These include gender differences, prosthesis education received, prosthesis type, level of limb loss, the cause of ULL/D, and prosthesis embodiment and empowerment.

Although this list is not comprehensive, these variables may assist in a greater understanding of the relationships between prosthesis use and embodiment, fall risk, and fall incidence.

Conclusion

The frequency of prosthesis use was associated with more embodiment of the prosthesis. However, neither prosthesis use nor embodiment affected whether an individual fell or not. Both the ABC Scale and the FES-I were able to indicate whether individuals with ULL/D were to report retrospective falls and may be a useful tool to utilize in the clinical environment to identify potential fall risk in this population. Because internal consistency was high with the embodiment questions utilized, further validation work of these questions as well as utilizing these questions in combination with other methods of measuring embodiment to assist with helping identify prosthesis embodiment would be beneficial. Further exploration to determine the effectiveness of the ABC Scale and FES-I to indicate whether someone who has ULL/D is more likely to fall would be beneficial to ensure the appropriate interventions are utilized to maximize stability and decrease the likelihood of falls.

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Table 1

Descriptive Statistics for Sample Characteristics (N = 84)

		Mdn (25^{th}, 75^{th})
Age (years)		50.50 (39.25, 59.75)
Prosthesis Use Frequency		49.50 (20.25, 89.25)
Years Since Limb Loss		9.80 (2.60, 27.00)
Years of Prosthesis Use		4.52 (1.50, 15.10)
		N (%)
Gender		
	Male	58 (69.0)
	Female	26 (31.0)
Limbs missing		
	Unilateral	60 (71.4)
	Bilateral	24 (28.6)
Lower Limb Loss		
	Yes	25 (29.8)
	No	59 (70.2)
Level of limb loss[a]		
	At or through shoulder	3 (3.6)
	Between shoulder and elbow	21 (25.0)
	At elbow	5 (6.0)
	Between elbow and wrist	48 (57.1)
	At wrist	7 (8.3)

Cause of limb loss	
Trauma/accident	46 (54.8)
Congenital	12 (14.3)
Infection	18 (21.4)
Cancer	6 (7.1)
Other	2 (2.4)
Prosthesis Type	
Passive/Cosmetic	8 (9.5)
Body Powered	30 (35.7)
Myoelectric/Motorized	38 (45.2)
Activity Specific	4 (4.8)
Hybrid	4 (4.8)
Medication	
Yes	7 (8.3)
No	73 (86.9)
Unsure	4 (4.8)

Note. [a]Most proximal level used for individuals with bilateral Upper Limb Loss/Difference

Table 2

Correlations Between Frequency of Prosthesis Use and ABC Scale, FES-I, and Embodiment (Unilateral/Bilateral)

	N	r_s	*p*
ABC Scale	84	.05	.670
FES-I	84	.02	.890
Embodiment Unilateral[a]	60	.49	< .001
Embodiment Bilateral[b]	24	.72	< .001

Note. ABC Scale = Activities-Specific Balance Confidence Scale; FES-I = Falls Efficacy Scale International

Table 3

Spearman rho Results of the Relationship of Embodiment (Unilateral/Bilateral) to ABC Scale and FES-I (N = 84)

	Embodiment Unilateral $n = 60$		Embodiment Bilateral $n = 24$	
	r_s	p	r_s	p
ABC Scale	.203	.119	.282	.181
FES-I	-.132	.316	-.370	.075

Note. ABC Scale = Activities-Specific Balance Confidence Scale; FES-I = Falls Efficacy International

Table 4

Sample Descriptives and Mann-Whitney U Test Comparison of Outcomes of Frequent Fallers and Non-Fallers (N = 84)

	Frequent Fallers *Mdn* (25^{th}, 75^{th})	Non-Fallers *Mdn* (25^{th}, 75^{th})	*p*	*Effect Size*
Prosthesis Use	65.00 (38.75, 98.00)	41.00 (16.00, 78.75)	.055	0.43
Embodiment Unilateral[a]	43.00 (37.00, 49.00)	41.00 (34.50, 46.50)	.489	0.18
Embodiment Bilateral[b]	37.00 (29.00, 40.00)	31.00 (28.00, 37.50)	.258	0.47
ABC Scale	75.31(56.25, 94.38)	92.19 (84.69, 98.91)	.002	0.73
FES-I Scale	28.00 (21.00, 39.00)	19.00 (17.00, 25.00)	< .001	0.87

Note. Frequent Fallers ≥2 Falls; Non-Fallers = 0-1 Falls; ABC Scale = Activities-Specific Balance Confidence Scale; FES-I = Falls Efficacy International

[a]*n* = 60

[b]*n* = 24

Appendix A

Survey

Prosthesis Use, Embodiment and their Relationship to Balance Confidence and Falls

Q1 **Research Study**: Embodiment on Balance Confidence, Fear of Falling, and Falls in Individuals with Upper Limb Loss or Difference
IRB Study Number: STU#00208178
Investigators: Kristi Turner, MHS, OTR/L and Dr. Matthew Major, PhD
Supported By: Northwestern University
Key Information about this research study: The following is a short summary of this study to help you decide whether to be a part of this study. The purpose of this study is to understand the impact of upper limb loss/difference on falls. You will be asked to complete a survey to help us identify ways to improve the safety of individuals with upper limb loss/difference. You will be asked to answer some questions on prosthesis use, fall history, balance confidence, fear of falling, and how you think of your prosthesis as part of your body. We will not be collecting any personal identifiable information from you and your participation is anonymous. We expect that you will be in this research study for 15-20 minutes to complete the survey. The primary risk of participation is a potential for emotional discomfort, but you have the option of not answering any question and can withdraw at any time. Although there is not a direct benefit to you participating in the study, the findings may help us improve the care for individuals with upper limb loss or difference. **Why am I being asked to take part in this research study?** We are asking you to take part in this research study because you are atleast 18 years of age, and have upper limb loss/difference at the wrist level or higher in atleast one arm. **What should I know about a research study?** · Whether or not you take part is up to you. · You can choose not to take part. · You can agree to take part and later change your mind. · Your decision will not be held against you. **If you say that "Yes, you want to be in this research," here is what you will do** You will be asked to complete an online survey. **What happens if I do not want to be in this research or if I say "Yes", but I change my mind later?** You can decide not to participate in this research or you can start and then decide to leave the research at any time and it will not be held against you. To do so, simply exit the survey.
What happens to the information collected for the research? Efforts will be made to limit the use and disclosure of your personal information, including research study to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB and other representatives of this institution. The data collected from this survey is anonymous, does not include identifying information, and will be shared with University of Indianapolis to assist with data analysis.
This survey is being hosted by Qualtrics® and involves a secure connection. Terms of service, addressing confidentiality, may be viewed at https://www.qualtrics.com/privacy-statement. **Who can I talk to?** If you have questions, concerns, or complaints talk to the Principal Investigator Dr. Matthew Major, PhD at matthew-major@northwestern.edu or (312) 503-5731 or Kristi Turner, MHS, OTR/L at turnerk@uindy.edu or (312) 238-1364. This research has been reviewed and approved by an Institutional Review Board ("IRB"). You may talk to them at (312) 503-9338 or irb@northwestern.edu if: · Your questions, concerns, or complaints are not being answered by the research team. · You cannot reach the research team. · You want to talk to someone besides the research team. · You have questions

about your rights as a research participant. · You want to get information or provide input about this research.
Consent If you want a copy of this consent for your records, you can print it from the screen. If you wish to participate, please click the "I Consent" button and you will be taken to the survey. If you do not wish to participate in this study, please select "I do not consent" or select X in the corner of your browser.
Please note that this survey will be best displayed on a laptop or desktop computer. Some features may be less compatible for use on a mobile device.

○ I consent, begin the study

○ I do not consent, I do not wish to participate

Skip To: End of Survey If Research Study: Embodiment on Balance Confidence, Fear of Falling, and Falls in Individuals with... = I do not consent, I do not wish to participate

End of Block: Informed Consent

Start of Block: Survey

Q2 What is the level of your upper limb loss or difference? **Please answer for both sides if the loss/difference is only on one side.**

	At or through the shoulder	Between the shoulder and the elbow	At the elbow	Between the elbow and the wrist	At the wrist	Part of the hand only	None	Prefer not to answer
Left side	○	○	○	○	○	○	○	○
Right side	○	○	○	○	○	○	○	○

Skip To: End of Survey If None is Equal to 2

Skip To: End of Survey If Part of the hand only is Equal to 2

Skip To: End of Survey If Prefer not to answer is Equal to 2

Q3 What was the cause for your upper limb loss?

- ◯ Trauma/accident
- ◯ Congenital (born with all or part of limb missing)
- ◯ Infection (sepsis, necrotizing fasciitis, meningitis, etc.)
- ◯ Cancer
- ◯ Vascular disease
- ◯ Other ____
- ◯ I do not know
- ◯ Prefer not to answer

Q4 How long has it been since your most recent major upper limb amputation or revision? Major amputation or revision refers to a change in level of limb loss where afterwards your limb loss is now higher in your arm. **If you have congenital limb difference, please mark Not Applicable.**

	Years	Months	Not Applicable	Prefer not to answer
			☐	☐

Q5 Which side do you choose to use to perform most activities? Sometimes referred to as your "dominant" side.

○ Left

○ Right

○ I used both sides equally

○ Prefer not to answer

Q6 Which side was your dominant side before you experienced upper limb loss? **If you have congenital limb difference, please mark Not Applicable.**

○ Left

○ Right

○ I use both sides equally

○ I do not know

○ Not Applicable

○ Prefer not to answer

Q7 Do you use a prosthetic arm?

○ Yes

○ No

○ Prefer not to answer

Skip To: Q26 If Do you use a prosthetic arm? = No

Skip To: Q26 If Do you use a prosthetic arm? = Prefer not to answer

Q8 What type of prosthetic arm do you currently use the most? **Please answer for both sides even if your limb loss/difference is only on one side.**

	Passive or Cosmetic	Body Powered	Myoelectric or Motorized	Activity Specific	Hybrid (combination of passive, body powered, and/or myoelectric)	I do not know	None	Prefer not to answer
Left	○	○	○	○	○	○	○	○
Right	○	○	○	○	○	○	○	○

Skip To: Q13 If Prefer not to answer was Equal to 2

Skip To: Q26 If None was Equal to 2

Q9
How is your prosthetic arm that you use the most held onto your body? This is commonly referred as the suspension method. Please answer for both sides even if your limb loss/difference is only on one side.
Check all that apply.

	Harness	Gel liner with pin lock OR lanyard strap	Suction	Osseointegration (direct attachment to the bone(	I do not know	None	Prefer not to answer	Other
Left	☐	☐	☐	☐	☐	☐	☐	☐
Right	☐	☐	☐	☐	☐	☐	☐	☐

Display This Question:

If How is your prosthetic arm that you use the most held onto your body? This is commonly referred a... = Left [Other]

Q9a Please describe "Other" on your Left side

____

Display This Question:

If How is your prosthetic arm that you use the most held onto your body? This is commonly referred a... = Right [Other]

Q9b Please describe "Other" on your Right side

____

Q10
How long have you been using the prosthetic arm that you use the most?

	Years	Months	Prefer not to answer
			☐

Q11 In a usual week, how many days do you use the prosthetic arm that you use the most? **Please answer for both sides even if your loss/difference is only on one side.**

Left Side	▼ I do not have limb loss on this side ... 7
Right Side	▼ I do not have limb loss on this side ... 7

Skip To: Q26 If I do not wear a prosthesis is equal to 2

Q12 In a usual day, how many hours do you use the prosthetic arm that you use the most?
Please answer for both sides even if your loss/difference is only on one side.

Left Side	▼ I do not have limb loss on this side ... Prefer not to answer
Right Side	▼ I do not have limb loss on this side ... Prefer not to answer

Skip To: Q26 If I do not wear a prosthetic arm is equal to 2

Q13 Please answer the following questions (Q14-Q25) about your experience with wearing the prosthetic arm you use the most. **If you have more than one prosthetic arm, please refer to the prosthetic arm you most frequently use.**

Q14 How often do you feel stable and balanced when you wear your prosthetic arm?

- ◯ Never 1
- ◯ Rarely 2
- ◯ Sometimes 3
- ◯ Often 4
- ◯ Always 5
- ◯ Prefer not to answer

Q15 How would you say your trunk/torso leans when wearing your prosthetic arm? If have loss of both of your upper limbs, please select Not Applicable.

- ◯ Completely towards intact side 1
- ◯ Completely towards side of limb loss 2
- ◯ Somewhat towards intact side3
- ◯ Somewhat towards side of limb loss/difference 4
- ◯ No lean towards either side 5
- ◯ Not Applicable
- ◯ Prefer not to answer

Q16 To what extent do you feel that your prosthetic arm is a part of your body?

- Not at all 1
- Partially 2
- Somewhat 3
- Mostly 4
- Completely 5
- Prefer not to answer

Q17 In a usual day, how often do you have a habit of unintentionally touching your prosthetic arm?

- Never 1
- Rarely 2
- Sometimes 3
- Often 4
- Always 5
- Prefer not to answer

Q18 How often do you feel that when something touches your prosthetic arm it touches your body?

- Never 1
- Rarely 2
- Sometimes 3
- Often 4
- Always 5
- Prefer not to answer

Q19 How accurately do you perceive the position and location of your prosthetic arm with your eyes closed?

- Poor Accuracy 1
- Fair Accuracy 2
- Good Accuracy 3
- Very Good Accuracy 4
- Excellent Accuracy 5
- Prefer not to answer

Q20 Please rate how quickly you move your prosthetic arm when you intend to move it?

○ Very slow 1

○ Slow 2

○ Moderate 3

○ Fast 4

○ Very fast 5

○ Prefer not to answer

Q21 Compared to your intact arm, how accurately do you move your prosthetic arm? **If have loss of both of your upper limbs, please select Not Applicable.**

○ Poor Accuracy 1

○ Fair Accuracy 2

○ Good Accuracy 3

○ Very Good Accuracy 4

○ As Accurately as Intact Side 5

○ Not Applicable

○ Prefer not to answer

Q22 Compared to your intact limb, how difficult is it to move your prosthetic arm? **If have loss of both of your upper limbs, please select Not Applicable.**

- ○ Extremely difficult 1
- ○ Very difficult 2
- ○ Moderately difficult 3
- ○ Slightly difficult 4
- ○ As easy as intact side 5
- ○ Not Applicable
- ○ Prefer not to answer

Q23 How much do you agree or disagree with the following statement: My prosthetic arm is indispensable to me or something I cannot be without.

- ○ Strongly Disagree 1
- ○ Disagree 2
- ○ Neither Agree nor Disagree 3
- ○ Agree 4
- ○ Strongly Agree 5
- ○ Prefer not to answer

Q24 How much do you agree or disagree with the following statement: I use my prosthetic arm to gesture when I communicate.

○ Strongly Disagree 1

○ Disagree 2

○ Neither Agree nor Disagree 3

○ Agree 4

○ Strongly Agree 5

○ Prefer not to answer

Q25 How much do you agree or disagree with the following statement:
I wear my prosthetic arm everywhere I go, I do not leave my house without it.

○ Strongly Disagree 1

○ Disagree 2

○ Neither Agree nor Disagree 3

○ Agree 4

○ Strongly Agree 5

○ Prefer not to answer

Q26 A fall is defined as coming to rest accidentally on the ground or other lower level, other than as a result of lost consciousness, a violent blow, stroke, or epileptic seizure.For questions Q27-Q31, please answer about your history of falls.

Q27 How many times have you fallen in the past 6 months?

▼ 0 ... Prefer not to answer

Q28 How many times have you fallen in the past 12 months?

▼ 0 ... Prefer not to answer

Skip To: Q32 If How many times have you fallen in the past 12 months? = 0

Q29 What activities were you doing during your most recent fall?

○ Physical exercise/sports

○ Walking up or down stairs

○ Sit to stand or stand to sit

○ Walking indoors

○ Walking outdoors

○ Performing daily care (dressing, grooming, bathing, toileting)

○ Other ____

○ Prefer not to answer

Q30 What do you believe caused you to fall during your most recent fall?

○ Loss of Balance

○ Tripped

○ Slipped

○ Pushed or Pulled

○ Fatigue

○ Dizziness

○ Other ____

○ I do not know

○ Prefer not to answer

Q31
Were you injured (caused you pain for more than 1 day, required you to change how you do activities or required medical attention) from your most recent fall?

○ Yes

○ No

○ Prefer not to answer

Q32 For each of the following activities listed in questions Q33-Q48, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale from 0% to 100%.
If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as if you were using these supports.

Q33 How confident are you that you will not lose your balance or become unsteady when you walk around the house?

○ No Confidence 0%

○ 10%

○ 20%

○ 30%

○ 40%

○ 50%

○ 60%

○ 70%

○ 80%

○ 90%

○ Completely Confident 100%

○ Prefer not to answer

Q34 How confident are you that you will not lose your balance or become unsteady when you walk up or down stairs?

○ No Confidence 0%

○ 10%

○ 20%

○ 30%

○ 40%

○ 50%

○ 60%

○ 70%

○ 80%

○ 90%

○ Completely Confident 100%

○ Prefer not to answer

Q35 How confident are you that you will not lose your balance or become unsteady when you bend over and pick up something off the floor?

○ No Confidence 0%

○ 10%

○ 20%

○ 30%

○ 40%

○ 50%

○ 60%

○ 70%

○ 80%

○ 90%

○ Completely Confident 100%

○ Prefer not to answer

Q36 How confident are you that you will not lose your balance or become unsteady when you reach for a small can off a shelf at eye level?

- ○ No Confidence 0%
- ○ 10%
- ○ 20%
- ○ 30%
- ○ 40%
- ○ 50%
- ○ 60%
- ○ 70%
- ○ 80%
- ○ 90%
- ○ Completely Confident 100%
- ○ Prefer not to answer

Q37 How confident are you that you will not lose your balance or become unsteady when you stand on your tiptoes and reach for something above your head?

- No Confidence 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- Completely Confident 100%
- Prefer not to answer

Q38 How confident are you that you will not lose your balance or become unsteady when you sweep the floor?

- No Confidence 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- Completely Confident 100%
- Prefer not to answer

Q39 How confident are you that you will not lose your balance or become unsteady when you walk outside the house to a parked car in the driveway?

- ◯ No Confidence 0%
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ Completely Confident 100%
- ◯ Prefer not to answer

Q40 How confident are you that you will not lose your balance or become unsteady when you stand on a chair and reach for something?

- No Confidence 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- Completely Confident 100%
- Prefer not to answer

Q41 How confident are you that you will not lose your balance or become unsteady when you get in or out of a car?

- No Confidence 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- Completely Confident 100%
- Prefer not to answer

Q42 How confident are you that you will not lose your balance or become unsteady when you walk across a large parking lot?

- No Confidence 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- Completely Confident 100%
- Prefer not to answer

Q43 How confident are you that you will not lose your balance or become unsteady when you walk up or down a ramp?

- No Confidence 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- Completely Confident 100%
- Prefer not to answer

Q44 How confident are you that you will not lose your balance or become unsteady when you walk in a crowded place where people rapidly walk past you?

- ○ No Confidence 0%
- ○ 10%
- ○ 20%
- ○ 30%
- ○ 40%
- ○ 50%
- ○ 60%
- ○ 70%
- ○ 80%
- ○ 90%
- ○ Completely Confident 100%
- ○ Prefer not to answer

Q45 How confident are you that you will not lose your balance or become unsteady when you are bumped into by people when you are walking?

- ◯ No Confidence 0%
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ Completely Confident 100%
- ◯ Prefer not to answer

Q46 How confident are you that you will not lose your balance or become unsteady when you step on or off an escalator while holding the rail?

- No Confidence 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- Completely Confident 100%
- Prefer not to answer

Q47 How confident are you that you will not lose your balance or become unsteady when you step on or off an escalator while holding items so that you cannot hold the railing?

- No Confidence 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%
- Completely Confident 100%
- Prefer not to answer

Q48 How confident are you that you will not lose your balance or become unsteady when walk outside on icy or slippery sidewalks?

○ No Confidence 0%

○ 10%

○ 20%

○ 30%

○ 40%

○ 50%

○ 60%

○ 70%

○ 80%

○ 90%

○ Completely Confident 100%

○ Prefer not to answer

Q49 For each of the following activities in questions Q50-Q65, please reply thinking about how you usually do the activity. If you use a mobility aid (wheelchair, walker, etc.), think about how concerned you are about falling when using that aid. **If you currently don't do the activity (e.g. if someone does your shopping for you), please answer to show whether you think you would be concerned about falling IF you did the activity.**
Please pick the box which is closest to your own opinion to show how concerned you are that you might fall if you did this activity.

Q50 How concerned are you that you might fall when you are cleaning the house (e.g. sweep, vacuum or dust)?

- ◯ Not at all concerned
- ◯ Somewhat concerned
- ◯ Fairly concerned
- ◯ Very concerned
- ◯ Prefer not to answer

Q51 How concerned are you that you might fall when you are getting dressed or undressed?

- ◯ Not at all concerned
- ◯ Somewhat concerned
- ◯ Fairly concerned
- ◯ Very concerned
- ◯ Prefer not to answer

Q52 How concerned are you that you might fall when you are preparing simple meals?

- ◯ Not at all concerned
- ◯ Somewhat concerned
- ◯ Fairly concerned
- ◯ Very concerned
- ◯ Prefer not to answer

Q53 How concerned are you that you might fall when you are taking a bath or shower?

- Not at all concerned
- Somewhat concerned
- Fairly concerned
- Very concerned
- Prefer not to answer

Q54 How concerned are you that you might fall when you are going to the shop?

- Not at all concerned
- Somewhat concerned
- Fairly concerned
- Very concerned
- Prefer not to answer

Q55 How concerned are you that you might fall when you are getting in or out of a chair?

- Not at all concerned
- Somewhat concerned
- Fairly concerned
- Very concerned
- Prefer not to answer

Q56 How concerned are you that you might fall when you are going up or down stairs?

- Not at all concerned
- Somewhat concerned
- Fairly concerned
- Very concerned
- Prefer not to answer

Q57 How concerned are you that you might fall when you are walking around in the neighborhood?

- Not at all concerned
- Somewhat concerned
- Fairly concerned
- Very concerned
- Prefer not to answer

Q58 How concerned are you that you might fall when you are reaching for something above your head or on the ground?

- Not at all concerned
- Somewhat concerned
- Fairly concerned
- Very concerned
- Prefer not to answer

Q59 How concerned are you that you might fall when you are going to answer the telephone before it stops ringing?

◯ Not at all concerned

◯ Somewhat concerned

◯ Fairly concerned

◯ Very concerned

◯ Prefer not to answer

Q60 How concerned are you that you might fall when you are walking on a slippery surface (e.g. wet or icy)?

◯ Not at all concerned

◯ Somewhat concerned

◯ Fairly concerned

◯ Very concerned

◯ Prefer not to answer

Q61 How concerned are you that you might fall when you are visiting a friend or relative?

◯ Not at all concerned

◯ Somewhat concerned

◯ Fairly concerned

◯ Very concerned

◯ Prefer not to answer

Q62 How concerned are you that you might fall when you are walking in a place with crowds?

- Not at all concerned
- Somewhat concerned
- Fairly concerned
- Very concerned
- Prefer not to answer

Q63 How concerned are you that you might fall when you are walking on an uneven surface (e.g. rocky ground, poorly maintained pavement)?

- Not at all concerned
- Somewhat concerned
- Fairly concerned
- Very concerned
- Prefer not to answer

Q64 How concerned are you that you might fall when you are walking up or down a slope?

- Not at all concerned
- Somewhat concerned
- Fairly concerned
- Very concerned
- Prefer not to answer

Q65 How concerned are you that you might fall when you are going out to a social event (e.g. religious service, family gathering or club meeting)?

- ◯ Not at all concerned
- ◯ Somewhat concerned
- ◯ Fairly concerned
- ◯ Very concerned
- ◯ Prefer not to answer

Q66 For questions Q67-Q78, we would like to gather some basic health information.
Q67 Do you have limb loss or difference in you lower limb(s)?

- ◯ Yes
- ◯ No
- ◯ Prefer not to answer

Skip To: Q72 If Do you have limb loss or difference in you lower limb(s)? = No

Skip To: Q72 If Do you have limb loss or difference in you lower limb(s)? = Prefer not to answer

Q68
How long has it been since your most recent major lower limb amputation or revision? Major amputation or revision refers to a change in level of limb loss where afterwards your limb loss now higher in your leg.
If you have congenital limb difference, please mark Not Applicable.

	Years	Months	Not Applicable	Prefer not to answer

			☐	☐

Q69 What is the level of your lower limb loss or difference? Please answer for both sides even if your loss/difference is only on one side.

	At the hip	Between the hip and the knee	At the knee	Between the knee and the ankle	At the ankle	Part of the foot only	None	Prefer not to answer
Left Side	○	○	○	○	○	○	○	○
Right Side	○	○	○	○	○	○	○	○

Skip To: Q72 If None is Equal to 2

Q70 In a usual week, how many days do you use your leg prosthesis? Please answer for both sides even if your loss/difference is only on one side.

	Not Applicable	I do not wear a prosthesis	1	2	3	4	5	6	7	Prefer not to answer
Left Side	○	○	○	○	○	○	○	○	○	○
Right Side	○	○	○	○	○	○	○	○	○	○

Skip To: Q72 If Not Applicable is Equal to 2

Skip To: Q72 If I do not wear a prosthesis is Equal to 2

Skip To: Q72 If Prefer not to answer is Equal to 2

Q71 In a usual day, how many hours do you use your leg prosthesis?
Please answer for both sides even if your loss/difference is only on one side.

Left Side	▼ Not Applicable ... Prefer not to answer
Right Side	▼ Not Applicable ... Prefer not to answer

Q72 Do you regularly use a mobility aid in your home or community? **If so, please select the mobility aid you use the most.**

- ○ I do not use any mobility aids
- ○ Crutches
- ○ Cane
- ○ Walker
- ○ Scooter
- ○ Wheelchair
- ○ Other ____
- ○ Prefer not to answer

Q73 Has a doctor ever told you that you have any of the following conditions? Please select **ALL** that apply.

☐ Arthritis (rheumatoid or osteoarthritis)

☐ Osteoporosis

☐ Asthma

☐ Chronic obstructive pulmonary disease (COPD), acquired respiratory disease distress syndrome (ARDS), or emphysema

☐ Angina (Chest pain)

☐ Congestive heart failure (or heart disease)

☐ Heart attack (myocardial infarct)

☐ Neurological disease (such as Multiple Sclerosis or Parkinson's)

☐ Stroke or TIA (transient ischemic attack)

☐ Peripheral vascular disease

☐ Diabetes (types I or II)

☐ Upper gastrointestinal disease (ulcer, hernia, reflux)

☐ Depression

☐ Anxiety or panic disorders

☐ Visual impairment (such as cataracts, glaucoma, macular degeneration)

☐ Hearing impairment (very hard of hearing, even with hearing aids)

☐ Degenerative disc disease (back disease, spinal stenosis, or severe chronic back pain)

☐ ☐ None

☐ Prefer not to answer

Q74 Do you take any medications that may affect your balance or vision?

◯ Yes

◯ No

◯ I do not know

◯ Prefer not to answer

Q75 What is your age?

▼ Prefer not to answer ... 120 years old

Q76 What is your current height?
If you have lower limb loss/difference and don't wear a prosthesis, please estimate.
Feet
Inches

▼ Prefer not to answer ... 7 ~ 11

Q77 What is your current estimated weight when not wearing your prosthesis?

▼ Prefer not to answer ... 450 lbs

Q78 What is your sex?

◯ Male

◯ Female

◯ Prefer not to answer

Q79 Have you completed a survey about upper limb prosthetics and falls in the past two years?

◯ Yes

◯ No

◯ Maybe

Appendix B

Activities-Specific Balance Confidence Scale

Instructions to Participants:
For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale form 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as it you were using these supports.

The Activities-specific Balance Confidence (ABC) Scale

For each of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

0% 10 20 30 40 50 60 70 80 90 100%
no confidence completely confident

"How confident are you that you will not lose your balance or become unsteady when you…
…walk around the house? ____%
…walk up or down stairs? ____%
…bend over and pick up a slipper from the front of a closet floor ____%
…reach for a small can off a shelf at eye level? ____%
…stand on your tiptoes and reach for something above your head? ____%
…stand on a chair and reach for something? ____%
…sweep the floor? ____%
…walk outside the house to a car parked in the driveway? ____%
…get into or out of a car? ____%
…walk across a parking lot to the mall? ____%
…walk up or down a ramp? ____%
…walk in a crowded mall where people rapidly walk past you? ____%
…are bumped into by people as you walk through the mall?____%
… step onto or off an escalator while you are holding onto a railing? ____%
… step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ____%
…walk outside on icy sidewalks? ____%

Appendix C

Falls Efficacy Scale – International

FES-I

Now we would like to ask some questions about how concerned you are about the possibility of falling. Please reply thinking about how you usually do the activity. If you currently don't do the activity (e.g. if someone does your shopping for you), please answer to show whether you think you would be concerned about falling IF you did the activity. For each of the following activities, please tick the box which is closest to your own opinion to show how concerned you are that you might fall if you did this activity.

		Not at all concerned *1*	*Somewhat concerned* *2*	*Fairly concerned* *3*	*Very concerned* *4*
1	Cleaning the house (e.g. sweep, vacuum or dust)	*1* ☐	*2* ☐	*3* ☐	*4* ☐
2	Getting dressed or undressed	*1* ☐	*2* ☐	*3* ☐	*4* ☐
3	Preparing simple meals	*1* ☐	*2* ☐	*3* ☐	*4* ☐
4	Taking a bath or shower	*1* ☐	*2* ☐	*3* ☐	*4* ☐
5	Going to the shop	*1* ☐	*2* ☐	*3* ☐	*4* ☐
6	Getting in or out of a chair	*1* ☐	*2* ☐	*3* ☐	*4* ☐
7	Going up or down stairs	*1* ☐	*2* ☐	*3* ☐	*4* ☐
8	Walking around in the neighbourhood	*1* ☐	*2* ☐	*3* ☐	*4* ☐
9	Reaching for something above your head or on the ground	*1* ☐	*2* ☐	*3* ☐	*4* ☐
10	Going to answer the telephone before it stops ringing	*1* ☐	*2* ☐	*3* ☐	*4* ☐
11	Walking on a slippery surface (e.g. wet or icy)	*1* ☐	*2* ☐	*3* ☐	*4* ☐
12	Visiting a friend or relative	*1* ☐	*2* ☐	*3* ☐	*4* ☐
13	Walking in a place with crowds	*1* ☐	*2* ☐	*3* ☐	*4* ☐
14	Walking on an uneven surface (e.g. rocky ground, poorly maintained pavement)	*1* ☐	*2* ☐	*3* ☐	*4* ☐
15	Walking up or down a slope	*1* ☐	*2* ☐	*3* ☐	*4* ☐
16	Going out to a social event (e.g. religious service, family gathering or club meeting)	*1* ☐	*2* ☐	*3* ☐	*4* ☐

FES-I: Prof Lucy Yardley and Prof Chris Todd

Appendix D

Embodiment Questionnaire

Please answer the following questions about your experience with wearing the prosthetic arm you use the most. If you have more than one prosthetic arm, please refer to the prosthetic arm you most frequently use.

1. How often do you feel stable and balanced when you wear your prosthetic arm?

Never 1	Rarely 2	Sometimes 3	Often 4	Always 5	Prefer not to answer

2. How would you say your trunk/torso leans when wearing your prosthetic arm? If have loss of both of your upper arms, please select Not Applicable.

Completely towards intact side 1	Completely towards side of limb loss 2	Somewhat towards intact side 3	Somewhat towards side of limb loss/difference 4	No lean towards either side 5	Not applicable	Prefer not to answer

3. To what extent do you feel that your prosthetic arm is part of your body?

Not at all 1	Partially 2	Somewhat 3	Mostly 4	Completely 5	Prefer not to answer

4. In a usual day, how often do you have a habit of unintentionally touching your prosthetic arm?

Never 1	Rarely 2	Sometimes 3	Often 4	Always 5	Prefer not to answer

5. How often do you feel that when something touches your prosthetic arm it touches your body?

Never 1	Rarely 2	Sometimes 3	Often 4	Always 5	Prefer not to answer

6. How accurately do you perceive the position and location of your prosthetic arm with your eyes closed?

Poor accuracy 1	Fair Accuracy 2	Good Accuracy 3	Very good accuracy 4	Excellent accuracy 5	Prefer not to answer

7. Please rate how quickly you move your prosthetic arm when you intend to move it?

Very slow 1	Slow 2	Moderate 3	Fast 4	Very fast 5	Prefer not to answer

8. Compared to your intact arm, how accurately do you move your prosthetic arm? If have loss of both of your upper limbs, please select Not Applicable.

Poor Accuracy 1	Fair Accuracy 2	Good Accuracy 3	Very good accuracy 4	As Accurately as Intact Side 5	Not Applicable	Prefer not to answer

9. Compared to your intact limb, how difficult is it to move your prosthetic arm? If have loss of both of your upper limbs, please select Not Applicable.

Extremely difficult 1	Very difficult 2	Moderately difficult 3	Slightly difficult 4	As easy as intact side 5	Not Applicable	Prefer not to answer

10. How much do you agree or disagree with the following statement: My prosthetic arm is indispensable to me or something I cannot be without.

Strongly Disagree 1	Disagree 2	Neither Agree nor Disagree 3	Agree 4	Strongly Agree 5	Prefer not to answer

11. How much do you agree or disagree with the following statement: I use my prosthetic arm to gesture when I communicate.

Strongly Disagree 1	Disagree 2	Neither Agree nor Disagree 3	Agree 4	Strongly Agree 5	Prefer not to answer

12. How much do you agree or disagree with the following statement: I wear my prosthetic arm everywhere I go, I do not leave my house without it.

Strongly Disagree 1	Disagree 2	Neither Agree nor Disagree 3	Agree 4	Strongly Agree 5	Prefer not to answer