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Association between balance confidence and basic walking abilities in people with unilateral transtibial lower-limb amputations: A cross-sectional study

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Running Head: Balance confidence and gait in amputees.

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ABSTRACT

Introduction: Falls are common for people with lower limb amputations (PLLA). Low balance confidence is also prevalent, worse in PLLA not reporting walking automaticity and is known to negatively affect prosthesis use, social engagement, and quality of life. Moreover, walking with a prosthesis requires continuous attention. Low balance confidence may act as a distractor imposing an additional cognitive load on the already cognitively demanding task of walking with a prosthesis.

Materials and Methods: Adults with unilateral, transtibial amputations were recruited. The Activities-specific Balance Confidence (ABC) scale quantified balance confidence. The L Test assessed basic walking abilities under single-task (usual) and dual-task (walking while counting backwards) conditions. The relative change in gait and secondary task performance between conditions (i.e., dual-task cost) was calculated. Separate multivariable linear regressions examined the association of balance confidence on the L Test.

Results: Forty-four PLLA (56.6±12.6 years) participated. An independent association of the ABC to single-task ($p<0.001$, $R^2=0.56$) and dual-task ($p=0.008$, $R^2=0.43$) L Test performance was observed. A 1% ABC increase was related with a 0.24 (95%CI: 0.35, 0.14) and 0.23 (95%CI: 0.39, 0.06) second reduction with the single-task and dual-task L Test, respectively. No association to dual-task cost was observed.

Conclusions: Balance confidence influences basic walking abilities, yet does not modulate the added cognitive load associated with dual-task. Interventions that address balance confidence

may be beneficial throughout rehabilitation. This research is novel and offers the possibility for alternative avenues for focus in rehabilitation and falls-prevention in a population at high risk for falls.

Keywords: Amputation, fear, performance anxiety, accidental falls, walking, multitasking behavior.

INTRODUCTION

Each year 7,405 Canadians have a lower limb amputation.[1] The average age for people undergoing a lower limb amputation is 65 years old,[1] and most amputations result from diabetes or peripheral vascular disease which are associated with chronic vascular damage that results in somatosensory and motor dysfunction.[2,3] Importantly, over 50% of people with lower limb amputations (PLLA) sustain a fall at least once annually,[4] and falls can have serious physical and psychological consequences, such as a concern for falling that may impact prosthesis adherence, social interaction, and quality of life.[5]

A concern for falls is a multidimensional term used to encompass the negative psychological factors associated with falls.[6] Fear of falling, falls-related self-efficacy, mobility-related self-efficacy, consequences of falling and perceptions on falls, each provide unique avenues to understanding concern for falls.[7] Among subdomains of concern for falling, self-efficacy, the belief that one can achieve a specific task,[8] remains the most widely examined.[6,7] Self-efficacy has been mainly studied through balance confidence, the belief one is able to achieve a task without losing balance or becoming unsteady.[9] In PLLA, balance confidence is particularly low even in those most experienced at a using a prosthesis for walking.[10] As most falls occur while walking,[11] and knowing ambulation is the most important factor to life satisfaction,[12] examining the relationship that exists between a concern for falls and walking is needed to improve our understanding of PLLA rehabilitation.

Prosthesis use increases subjective reports of cognitive demands, with an estimated 41% reporting having to concentrate on every step they take.[4] In general, cognitive resources are finite;[13] however, PLLA are impacted by a high prevalence of impairment limiting the capacity for the allocation of cognitive resources[14,15]. Dual-task gait testing, walking while completing a second task, allows for the quantification of the inter-relationship between cognitive and motor function.[13] If cognitive demands surpass a person's cognitive capacity, then performance of one or both tasks is adversely affected.[13] The dual-task cost refers to the relative change in performance between single-task and dual-task.[13] Quantitative research supports an increase in cognitive demands for PLLA during dual-task walking, and which is accompanied by a reduction in gait pace, rhythm, and increased asymmetry.[16] In PLLA, balance confidence is significantly impaired in those reporting having to think about every step they take (i.e., non-automatic gait).[10] In other populations, reduced balance confidence is associated with anxiety about falling, which has been shown to increase attentional needs and results in adverse gait.[17] Therefore, suggesting that a relationship may exist between balance confidence and walking, whereby low balance confidence acts as a distractor and exert an additional load onto the already cognitively demanding task of walking with a prosthesis.

Four studies have assessed the effect that balance confidence has with the mobility of community-dwelling PLLA.[5,18–20] Miller et al.[5] and Wong et al.[19] concluded that reduced balance confidence was independently associated with decreased self-reported mobility. More recently, Mandel et al.[20] reported a moderate positive correlation between balance confidence and total number of steps, while Sions et al.[18] determined that reduced balance confidence was independently associated with an impaired Timed Up & Go and the Six Minute Walking Test performance. The literature on this topic to date has relied on indirect assessments of mobility, such as using questionnaires, correlational analyses, or the use of tests of physical function not specifically designed for this population. In contrast, the L Test of Functional Mobility (L Test) is an objective mobility test that was designed to assess basic walking ability.[21] The L Test evaluates level walking, sit-to-stand and stand-to-sit transfers, and turns to both directions that are considered the minimal needs for mobility in the home.[21] Yet, walking in the real world also requires the ability to perform simultaneous tasks while walking.[13] The L Test with a dual-task component becomes a complex clinical protocol that is more relevant to everyday mobility and the challenges often experienced by PLLA.

The main objective of the present manuscript was to examine the association between balance confidence and L Test performance in single-task and dual-task conditions in PLLA. It was hypothesized that decreased balance confidence would be independently associated with a longer time to complete the L Test, and with a stronger effect being observed during dual-task testing.

METHODS

Participants

This was a secondary analysis of a study of community-dwelling individuals recruited from the outpatient prosthetic clinic of the Amputee Rehabilitation Program at Parkwood Institute in London, Ontario (March 2016-January 2017).[22] Individuals were approached during a regularly scheduled appointment with their physiatrist, thus comprising a convenience sample. The inclusion criteria was: ≥18 years of age; English language proficiency; have a lower limb amputation; and >6 months of daily experience using a lower limb prosthesis for walking. For this study, only people with a unilateral, transtibial level amputation were included as these are the most common amputations and to minimize sample heterogeneity.[1,2] Excluded was anyone with neurological or physical issues secondary to their lower limb amputation (e.g., Parkinson's) that may significantly impact walking with a prosthesis as determined by the program physiatrist.

Participants provided written informed consent. The study was approved by the Health Sciences Research Ethics Board at the University of Western Ontario and by the Clinical Resources Impact Committee at the Lawson Health Research Institute in London, Ontario. Each collection took 30 minutes to complete.

Clinical and demographic characteristics collected were: age, sex, height and weight with their prosthesis to calculate body mass index, etiology and time since amputation, 12-month falls history (yes/no), mobility aid used, comorbidities using a standardized checklist, and cognitive status using the Montreal Cognitive Assessment (MoCA).[23] For the MoCA, scores range from 0-30, with higher scores indicating better cognitive function and those ≤25 being reflective of cognitive impairment.[23] A fall was defined as: "an unexpected event in which the participant comes to rest on the ground, floor, or lower level".[24] Number of prescription medications were extracted from the participant's medication list. Medical charts were reviewed to confirm demographic and medical information.

Outcome Measures

Balance confidence

The Activities-specifics Balance Confidence Scale (ABC) was used to assess balance confidence,[9] a form of falls-related self-efficacy.[6,7] The long-form ABC was used, which is a 16-item questionnaire that asks individuals to rate their level of balance confidence, from 0% (no confidence) to 100% (completely confident), when completing an array of daily activities without losing balance or becoming unsteady. The mean across all items represents the total score. A lower ABC indicates an increased level of concern for falls. The ABC test-retest reliability ranges between good to excellent (ICC range=0.80-0.94) and has been shown to be valid in this population.[25]

Basic walking abilities

The L Test of Functional Mobility, a modified Timed Up & Go, was used to assess basic walking abilities.[21] From a seated position on an armless chair, participants were asked upon hearing the word 'go' to stand, walk three meters, turn 90°, walk seven meters, turn 180°, and then backtrack the same path to the seated starting position. Tape on the ground was used to indicate turning points. Single-task (ST) performance was the time to complete the course once at a self-selected walking speed, which was recorded using a stopwatch.

After a seated five-minute break, a dual-task (DT) condition was completed. Participants walked while simultaneously subtracting 3's from a random number between 100-150 out loud. No instructions were given to prioritize any one task and all secondary task responses were recorded for number of responses and accuracy.

If applicable, participants used their walking aid to complete tests. One trial of each condition was performed by participants and recorded by the same assessor. The L test was first demonstrated and explained to the participant using a standardized set of instructions. The L Test protocol used in the present study has excellent test-retest reliability (ICC range=0.93-0.99) and has been shown to be valid among PLLA.[22]

Single-task cognitive testing

While sitting, participants were asked to complete 10 arithmetic subtractions by 3's from 100 to obtain an independent assessment of the cognitive task. The time to complete the test, the number of responses, and the accuracy of answers from the 10 subtractions were recorded to determine the correct response rate (*see data analysis section*).

Data Analysis

For clinical and demographic information, the normality of continuous variables was assessed using Shapiro-Wilks tests and a visual inspection of histograms and Q-Q plots. Age and MoCA scores were summarized using means and standard deviations, while other continuous variables did not meet normality and were reported as medians and interquartile ranges.

Two variables were calculated from single- and dual-task tests: walking task cost and cognitive task cost. Walking task cost was calculated as the relative difference between single-task and dual-task L Test conditions:

$$Walking\ Task\ Cost = \left[\frac{ST - DT}{ST}\right] x(100)$$

Similarly, cognitive task cost was depicted as the change in performance from the seated, single-task condition to the dual-task condition. First, the single-task correct response rate (CRR) was calculated to take into account accuracy and speed:

$$Correct\ response\ rate\ (CRR) = responses\ per\ second\ x\ percentage\ of\ correct\ responses$$

$$Cognitive\ Task\ Cost = \left[\frac{\text{CRR walking in DT} - \text{CRR seated}}{\text{CRR seated}}\right] x(100)$$

For walking and cognitive task cost, a negative value indicates poorer performance and a positive value indicates improved performance upon dual-task.

Four separate multivariable linear regression models were used to evaluate the independent association of balance confidence on: single-task L Test, dual-task L Test, walking task cost, and cognitive task cost. Regression models were examined for the assumptions of autocorrelation and homoscedasticity using the Durbin-Watson statistic and residual scatterplots, respectively; multicollinearity using variance inflation factors; and residual normality. As cognitive task cost did not meet normality assumptions, statistical analysis was carried out using square root transformed data. No outliers were detected and no data was missing.

Regressions were adjusted for the confounders of sex (male, female), etiology (vascular, non-vascular) and number of comorbidities (continuous) to yield the most parsimonious model. Confounders were selected according to clinical significance, previous research,[5,18,19] data availability, and an observed ≥10% change in the unstandardized ABC beta values with the introduction of each. The first regression block assessed the univariate relationship between the ABC and the L Test, while the second contained all confounders. No automatic procedure was used and variables were entered manually following hierarchal modelling.

An *a priori* analysis using G*Power (version 3.1.9.6)[26] estimated that 97% power could be attained assuming α=0.05, the use of four predictors (omnibus R^2=0.55),[5] and the availability of 44 participants. The software package SPSS version 25.0 (SPSS, Inc., Chicago, IL) was used for all statistical analyses with a 0.05 experiment-wise alpha.

RESULTS

Of 81 people approached, 68 were enrolled in the parent study,[22] and a subgroup of 44 participants with unilateral transtibial level amputations were included in the current analysis. The main reason for not enrolling in the initial study was living too far from the center (68.1%). (Table 1) The mean age was 56.6 ± 12.6 years, 86.4% were male, and close to half (45.5%) reported having an amputation due to vascular issues. The average MoCA score was 26.41 ± 2.33 (min: 20, max: 30) and 31.8% had impaired cognition. The median ABC score was 85.94% (min: 33.13%, max: 100.00%) and was higher than what is typically reported[10,27]. (Table 2) As expected, the median time to complete the L Test was longer for dual-task than single-task trials.

Multivariable linear regression modelling demonstrated an independent association of the ABC to single-task ($p<0.001$) and dual-task ($p=0.008$) L Test performance. (Table 3) A 1% ABC increase was related with a 0.24 (95% CI: 0.35, 0.14) and 0.23 (95% CI: 0.39, 0.06) second reduction with the single-task and dual-task L Test, respectively. Overall, 56% of the variance in single-task and 43% of the variance in dual-task L Test performance were explained by adjusted models. No associations between the ABC and walking or cognitive task cost were observed.

DISCUSSION

Decreased balance confidence was independently associated with longer times to complete the single-task and dual-task L Test in a sample of community-dwelling PLLA at the transtibial level. No association between balance confidence and the magnitude of change between conditions (i.e., dual-task cost) was observed. Our research expands on the literature to provide further support that balance confidence influences basic walking abilities when using a clinical test specifically designed for PLLA, yet has no influence over gait or cognitive dual-task cost.

Previous research by Miller et al.[5] and Wong et al.[19] established that reduced balance confidence was associated with impaired self-reported mobility. However, making inferences on objective mobility from self-reported assessments, or vice versa, is not recommended.[28] Our findings are consistent with Sions et al.[18] who also evaluated balance confidence using the ABC, but inquired on physical performance using other tests. Importantly, Sions et al.[18] recruited people with transtibial and transfemoral amputations while our study only included those with transtibial amputations. Individuals with transfemoral amputations have impaired performance in self-reported and objective mobility compared to those with transtibial amputations.[21,29] The absence of a knee joint increases balance instability and is a known falls risk factor.[4] It is unknown if the results may have been biased towards PLLA with transfemoral amputations, as Sions et al.[18] did not examine if a difference in mobility tests was observed according to level of amputation, nor was it controlled for in the regressions. Our study provides evidence for the effect of balance confidence on gait in a more homogeneous sample using a protocol that required a higher level of skill.

Contrary to our hypothesis, balance confidence was found not to be a contributing factor to the changes in gait or secondary task performance upon dual-task. Although these results are novel in PLLA, similar findings have been observed in people with Parkinson’s disease regardless of cognitive status.[30] In their study, Prell et al.[30] used a different measure for falls-related self-efficacy and gait protocol, yet also found that a relationship between self-efficacy and gait existed but not for the walking task cost. Perhaps reduced balance confidence increases falls risk via changes to gait, but not through modulations of the cognitive load of walking as per dual-task cost. Future research should explore balance confidence under more anxiety provoking scenarios (e.g., variations in lighting or walking surfaces) and how these conditions influence gait or our understanding of cognitive distractors. Also warranted is to expand on the present protocol and evaluate how other factors (e.g., falls history, cognitive status) influence the inter-relationship between balance confidence and gait at different timepoints of rehabilitation. Lastly, a concern for falls is multidimensional,[6,7] still only one subdomain was assessed. Future studies should examine the relationship that exists between different aspects of concern for falls and gait across different aetiologies, age groups, and levels of experience using a lower limb prosthesis.

A concern for falls is usually assessed through self-efficacy.[6,7] An inter-relationship exists between self-efficacy and the completion of progressively more complex activities, known as mastery experiences.[8] The more experience a person has with being successful at completing tasks, the higher their self-efficacy will be.[8] Participants in our study had already developed a variable level of proficiency for complex walking situations, including dual-task, through their experiences in the community. This level of experience walking with a prosthesis, coupled with the fact that all of our participants had an amputation at the transtibial level, may explain the higher balance confidence in our sample. As a result, the association presently reported between balance confidence and walking is likely an underestimate. Reduced balance confidence is very common in PLLA, persisting years after community re-integration and is significantly impaired in those not reporting walking automaticity.[10,31] Balance confidence is also associated with and predicts future social participation.[5,18] Low balance confidence can result in PLLA limiting their engagement in activities they are physically capable of performing which subsequently increases the challenge of tasks and the risk for falls due to deconditioning.[8] Therefore, interventions specifically targeting balance confidence are warranted due to its association to multiple aspects of life in PLLA, including simple and complex gait.

Even though mastery experiences are considered the most influential sources for self-efficacy, other strategies do exists.[8] Vicarious experiences can allow individuals to adjust expectations and model behaviour based on the observation of others, while verbal persuasion can facilitate the successful completion of difficult tasks previously believed to be outside of one's own capabilities.[8] Interventions such as home-based exercises or a multifaceted falls-prevention approach have been shown to increase balance confidence in older adults.[32] However, most interventions have relied on the administration of physical activity, home safety assessments, or falls risk education.[32] For PLLA, physical function and balance confidence are believed to be related yet distinct from one another.[28,33] Research has found that while physical function improves after discharge from prosthetic rehabilitation[28] there is an absence of change in balance confidence[33]. Indeed, and among community-dwelling older adults, it appears the most successful interventions target physical function alongside the additive use of therapeutic approaches that specifically address psychological aspects (e.g., self-perceived physical capacity, anxiety, etc.), such as through cognitive behavioural therapy or motivational interviewing.[34] Unfortunately, this is an area with little direction for healthcare professionals working with PLLA.[35] The gaps in the literature include a lack of protocols with demonstrated efficacy for the enhancement of self-efficacy, as well as preventative strategies specific to this population.

Our results should not be generalized to all PLLA as the sample was composed of only people with unilateral, transtibial amputations who were mainly males, considered higher functioning, and had a high balance confidence. Moreover, the range of time since amputation for the participants was wide and mastery of walking with a prosthesis and a concern for falls may differ at other rehabilitation stages. A study strength was the execution of a well-developed methodology and the recruitment of a homogenous sample of higher functioning PLLA from an outpatient setting.[1,2]

CONCLUSIONS

The Activities-specifics Balance Confidence Scale was independently associated with single-task and dual-task L Test performance in community-dwelling, transtibial users of prostheses. However, the impact of balance confidence was not greater in the dual-task condition, thus not contributing to the cognitive demands of dual-task gait. Routine care for PLLA should involve interventions specifically targeting balance confidence. Future research needs to examine how other factors, such as experience level, may affect the inter-relationship between balance confidence and gait.

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Table 1: Demographic and clinical characteristics of a sample of adult, prosthesis users with a transtibial level amputation.

Variable	**Mean ± SD, Median [IQR] or n (%) (n=44)**
Age (years)	56.6 ± 12.6
Sex, n (% male)	38 (86.4)
Height (m)	1.75 ± 0.08
Weight (Kg)	87.05 [75.49, 100.47]
Body Mass Index (kg/m^2)	27.58 [25.25, 33.24]
Amputation Etiology, n (%)	
DM and PVD	20 (45.5)
Trauma	17 (38.6)
Congenital	2 (4.5)
Cancer	1 (2.3)
Other (infection, etc.)	4 (9.1)
Time Since Amputation (years)	4.2 [1.7, 21.7]
History of Falls in the Past 12 Months, n (% yes)	15 (34.1)
Walking Aid, n (% yes)	8 (18.2)
Cane	5 (62.5)
Fore-arm crutches	2 (25.0)
Rollator	1 (12.5)
Montreal Cognitive Assessment Score	26.41 ± 2.33
Number of Medications	4.0 [1.0, 9.0]

Number of Comorbidities	2.0 [1.0, 3.0]
Summary of Comorbidities, n (% yes)	
DM	20 (45.5)
Hypertension	18 (40.9)
Osteoarthritis	11 (25.0)
Dyslipidemia	10 (22.7)
Other (anemia, angina, history of heart attack, etc.)	26 (59.1)

Footnote: DM: diabetes mellitus; IQR: interquartile range; PVD: peripheral vascular disease.

Table 2: Performance on the Activities-specifics Balance Confidence Scale, L Test of Functional Mobility, and walking task cost and cognitive task cost in a sample of adult, prosthesis users with a transtibial level amputation. (n=44)

Outcome	**Median [IQR]**
Activities-specifics Balance Confidence Scale (%)	85.94 [76.33, 95.32]
L Test, single-task (s)	24.11 [22.06, 32.27]
L Test, dual-task (s)	29.99 [25.19, 36.35]
Gait task cost (%)*	-15.12 [-27.69, -7.28]
Cognitive task cost (%)*	-16.86 [-39.25, 14.62]

Footnote: IQR: interquartile range; L Test: L Test of Functional Mobility. *, negative values are indicative of impaired performance upon dual-task testing relative to single-task trials.

Table 3: Multivariable linear regression modeling for the association of the Activities-specifics Balance Confidence Scale (independent variable) on the L Test of Functional Mobility performance (dependent variable) in people with a transtibial level amputation.

	Unadjusted			**Adjusted**			
Dependent variable	**unstandardized β (95%CI)**	**p-value**	**R^2**	**unstandardized β (95% CI)***	**p-value**	**R^2**	**ΔR^2 (confounders)**
L Test, single-task (s)	**-0.32 (-0.41, -0.22)**	**<0.001**	0.53	**-0.24 (-0.35, -0.14)**	**<0.001**	0.56	0.03
L Test, dual-task (s)	**-0.34 (-0.48, -0.20)**	**<0.001**	0.35	**-0.23 (-0.39, -0.06)**	**0.008**	0.43	0.08
Gait task cost (%)	-0.11 (-0.41, 0.20)	0.48	0.01	-0.19 (-0.53, 0.15)	0.27	0.13	0.13
Cognitive task cost (sqrt%)	0.04 (-0.03, 0.10)	0.25	0.01	0.07 (-0.004, 0.14)	0.06	0.04	0.03

Footnote: ABC: Activities-specifics Balance Confidence Scale; CI: confidence interval; L Test: L Test of Functional Mobility. *, regression modeling adjusted for sex (binary: male, female), etiology (binary: non-vascular, vascular), and number for comorbidities (continuous). Statistical significance was $p < 0.05$.