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Original Research

Virtual Assessment of Functional Mobility in Lower Extremity Prosthesis Clients: An Exploratory Study

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KEYWORDS
Artificial limb;
Home-based rehabilitation;
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Abstract *Objective:* To investigate the relationship between patient perception of lower extremity function and a home-based virtual clinician assessment of mobility in lower limb prosthesis clients.
Design: Descriptive observational study using a clinician-administered functional mobility survey and timed Up and Go test to assess lower extremity function under supervision.
Setting: Health Insurance Portability and Accountability Act-compliant online virtual platform.
Participants: Twelve lower limb loss clients currently using prostheses, aged ≥19 years, not pregnant, and with no stroke, seizure disorder, or cancer.
Interventions: Not applicable.
Main Outcome Measures: Main outcomes were mobility survey scores and mean timed Up and Go duration.
Results: Most participants reported significant ease of completing basic indoor ambulation and toileting tasks (66%-75%) and significant difficulty in running or prolonged ambulation activities (83%) requiring use of lower limb prosthesis. Timed Up and Go test was faster (11.0±2.9 s) than the reference range for transtibial prosthesis users and negatively associated with self-reported lower extremity functional status (r=−.70, P=.02).
Conclusions: Self-reported movement with lower limb prostheses at home and evaluation of mobility via a virtual platform is a feasible assessment modality that may reduce the frequency of therapy visits, defray some rehabilitation costs, and minimize the travel burden to distant prosthetic clinics.

List of abbreviations: LEFS, Lower Extremity Functional Scale; LLPC, lower limb prosthesis client; TUG, timed Up and Go.
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Limb amputation creates an enormous socioeconomic challenge in America. More than 2 million people live with an amputated limb,[1] resulting in >$10 billion in medical expenses annually.[2] Diabetes mellitus, trauma, and peripheral vascular disease resulting from atherosclerosis are the leading causes of amputations,[3-6] which occur more in the lower limbs.[7] After amputation, prosthetic rehabilitation is used to partially ameliorate mobility limitations and improve quality of life.[6,8-10]

Individuals with lower limb amputation(s) experience many challenges during rehabilitation and reintegration back into their home environment. Adapting to new ways of moving with their prosthesis and learning to carry out basic activities of daily living can be a daunting task. Furthermore, prosthetic prescription itself is a challenging process, often requiring multiple prosthetic socket designs and trials to improve fit and comfort and reduce skin irritation.[11] Lack of physical access to physical therapy clinics for follow-up care often poses a significant barrier to clients with lower limb amputations receiving quality prosthetic rehabilitation after hospital discharge.[11,12] Health care disparities compounded by limitations such as geographic location of prosthetic care, low socioeconomic status, poor education, and racial discrimination restrict access to adequate prosthetic rehabilitation services.[10-12]

Hospital-based outpatient care and home-based rehabilitation have been shown to be successful in cardiac rehabilitation patients with heart failure[13,14] and poststroke geriatric patients.[15] Home-based care resulted in comparable patient outcomes with no additional financial burden to the patient or provider[13-15] and improved patient quality of life.[13,14] Although the use of home-based exercise interventions after lower limb amputation is uncommon, some studies have shown that it may be an effective method to improve mobility and quality of life in prosthesis users postamputation.[10,16] There is therefore a need to explore home-based care as an alternative means to assess rehabilitation progress and functional independence of the lower limb prosthetic user outside the hospital environment. Considering the challenges lower limb prosthesis clients face in accessing available prosthetic care, a home-based care approach may help improve their functional independence and overall quality of life.

Thus, the purpose of this study was to:

1. Assess the feasibility of a home-based virtual assessment of lower extremity mobility of lower limb prosthetic clients (LLPCs) to inform a future randomized controlled trial.
2. Determine LLPC perception of functional mobility with their prosthesis in their home environment using a validated survey instrument.
3. Evaluate the relationship between LLPC perception of lower extremity function and a clinician-administered virtual assessment of lower extremity mobility of LLPCs in their home environment.

Methods

The patient-centered outcomes for this observational study were the Lower Extremity Functional Scale (LEFS), a component of the validated Orthotics Prosthetics Users' Survey,[17-19] and the timed Up and Go (TUG) test,[20-22] administered by a clinician via a secure Health Insurance Portability and Accountability Act-compliant Zoom[a] platform. All protocols for the study were conducted in accordance with the Declaration of Helsinki and were approved by the institutional review board (protocol number: 21-310 EP 2107). A snowball sampling method was used. A recruitment flyer was sent to clinicians and prosthetic rehabilitation centers and posted on several lower limb loss social media platforms. In addition, recruitment emails were sent to interested participants, and informed consent was obtained. The primary outcomes for the virtual study included the recruitment and retention of a minimum of 12 participants, which would provide baseline data for future follow-up studies.

Twelve participants aged 19-80 years completed the study. Inclusion criteria were individuals aged ≥19 years with lower extremity amputation who were currently using any lower extremity prosthesis. Exclusion criteria were LLPCs with (1) pre-existing acute or chronic medical conditions that can interfere with lower limb function such as stroke or seizure disorders; (2) lower limb amputations because of cancer; and (3) pregnancy (because of increased risk of falls).[23]

The LEFS component of the Orthotics Prosthetics Users' Survey is a 20-item validated instrument that measures lower extremity daily activities rated on a 5-level Likert scale ranging from "very easy," scored 4, to "cannot do this activity," scored 0. The LEFS also showed a satisfactory test-retest reliability with an intraclass correlation coefficient from 0.67-0.96.[18,21] The TUG test is a brief functional performance tool to assess basic mobility. This includes walking, turning while walking, balance, and transfers.[21] The TUG test demonstrated strong reliability with intraclass correlation coefficients from 0.98-0.86 and significant discriminative validity in average time for completion between individuals with below-knee and above-knee limb loss. The TUG test also exhibited convergent validity as indicated by moderate correlations with the Prosthetic Limb Users Survey of Mobility (ρ=−.56).[22] Participants were allowed to use their walking aids (if any) during testing.[20] The dependent variable for the study was the LEFS questionnaire scores as reported by the participants. Although the independent variable was the mean TUG duration as recorded by the clinician.

Interested participants were emailed the virtual study information letter with a Qualtrics link for providing informed consent, a video demonstration of the set-up instructions, and demonstration of the TUG test. In addition, the researcher sent a disposable measuring tape to participants via regular mail so they could measure the distance for the TUG test. A chaperone or caregiver was present with the participant for the virtual testing procedure to assist with the test set-up and ensure safety. A link to the Health Insurance Portability and Accountability Act-compliant secure Zoom platform was sent via email to participants who voluntarily gave informed consent.

Basic demographics were collected at the beginning of the Zoom session and included age, biological sex, date of amputation, injury etiology, level of amputation, number of past devices, and number of sockets used post amputation. Participants were in their home environment wearing their lower limb prosthesis and regular footwear and accompanied by a caregiver or acquaintance to ensure safety. An armchair was placed at a marked starting point, and a 10-foot uncluttered walk space was measured and marked on the floor. Participants completed one practice trial to become familiar with the TUG test, with the investigator answering any questions. Participants rested for 3 minutes, then completed 3 timed and recorded iterations of the TUG procedure separated by 3-5 minutes of rest as needed. The researcher gave the following instructions to the participant: "On the word GO, you will stand up from the chair, walk to the line on the floor at your regular pace, turn around, and walk back to the chair and sit down." The researcher started timing on the word "GO" and stopped timing when the participant sat again in the chair with their back resting against the backrest of the chair. The time in seconds to complete the TUG test was recorded. The researcher subsequently administered the 20-item LEFS survey to the participant. The virtual testing component took about 15 minutes to complete. Participants who completed the session were given the choice to receive a $50 electronic gift card.

All continuous data are presented as means and standard deviations, with categorical data presented as frequencies and percentages. Descriptive statistics were calculated for the LEFS responses. The reported LEFS scores were converted into a Rasch measure, which provides appropriately weighted scores on an increasing linear scale with "0" representing the lowest measure of lower extremity function and "100" representing the highest measure.[19] Bivariate Pearson correlation was used to measure the strength and direction of the linear relationship between the LEFS and TUG test scores. A simple linear regression was also calculated to assess the predictive value of the TUG test on LEFS scores. An a priori α level was set at.05 for statistical significance, and all statistical analyses were performed using IBM SPSS version 28.[b]

Results

Descriptive characteristics of the study sample are displayed in table 1. A total of 12 participants (5 women and 7 men) completed the study with a retention rate of 100%. Participant age ranged from 28-66 years (mean age of 48.3±12.8y) with the majority (66.7%) being middle-aged or older and predominantly White (75%). Diabetes, peripheral vascular disease, infections, and trauma were the reported clinical indications for amputation. Most of the participants had unilateral amputation (91.7%), and about half had below-knee amputation (58.3%).

Table 1 Participant demographics and general amputation characteristics.

Demographic	Characteristic	n (%)
Sex	Female	5 (41.7)
	Male	7 (58.3)
Age, y	19-39	4 (33.3)
	40-59	5 (41.7)
	≥ 60	3 (25.0)
Race	White	9 (75.0)
	Black	3 (25.0)
	Hispanic and other	0 (0)
Etiology of amputation	Diabetes and vascular diseases	3 (25.0)
	Trauma	4 (33.3)
	Infection	4 (33.3)
	Other	1 (8.3)
Amputation Type	Unilateral	11 (91.7)
	Bilateral	1 (8.3)
Amputation Level	Transtibial	7 (58.3)
	Transfemoral	5 (41.7)

The LEFS responses are represented in the summary plot (fig 1). Overall, participants reported a mean LEFS score of 55.1±4.4, indicating average functionality with lower extremity prostheses (a score of "0" corresponds to the lowest level and "100" the highest level of lower extremity function with prosthesis). Most participants (75%) reported they found it easy to "dress lower body," "get on and off the toilet," and "get up from a chair." About 66% of participants also reported they found it easy to "get in and out of a car," "climb one flight of stairs with a rail," and "carry a plate of food while walking." Half of the participants reported they found it very difficult to "run one block" whereas an additional 33.3% of participants disclosed they cannot run one block with their prosthesis. About 25% of participants also revealed they found it very difficult to "get up from the floor" and "walk in bad weather." All (100%) of the participants stated they either had little or no difficulty, found it easy, or very easy to "get in and out of the tub or shower," "get up from a chair," "get into and out of a car," "walk indoors," "carry a plate of food while walking," or "put on and take off their prosthesis."

The TUG data of 11 participants were analyzed. One participant was removed as an extreme outlier because of the time to complete the TUG task (over 2 standard deviations from the group mean value). The participant excluded was using a newly obtained transfemoral prosthesis during the testing, which likely affected his results. Participants reported a mean TUG value of 11.0±2.9 seconds (N=11), which is within the reference range for normal TUG values of lower limb prosthesis users (12.3±4.5 to 13.0±5.6).[21]

A Pearson correlation coefficient was computed to assess the relationship between LEFS and TUG scores. The scatter plot (fig 2) summarizes the results. Overall, there was a strong negative correlation between the mean LEFS scores and the mean TUG values, r(9)=.70, *P*=.02. Increases in self-reported LEFS scores (higher self-ratings of ability to complete daily activities) correlated with decreases in the time it took to complete the clinician virtually administered TUG

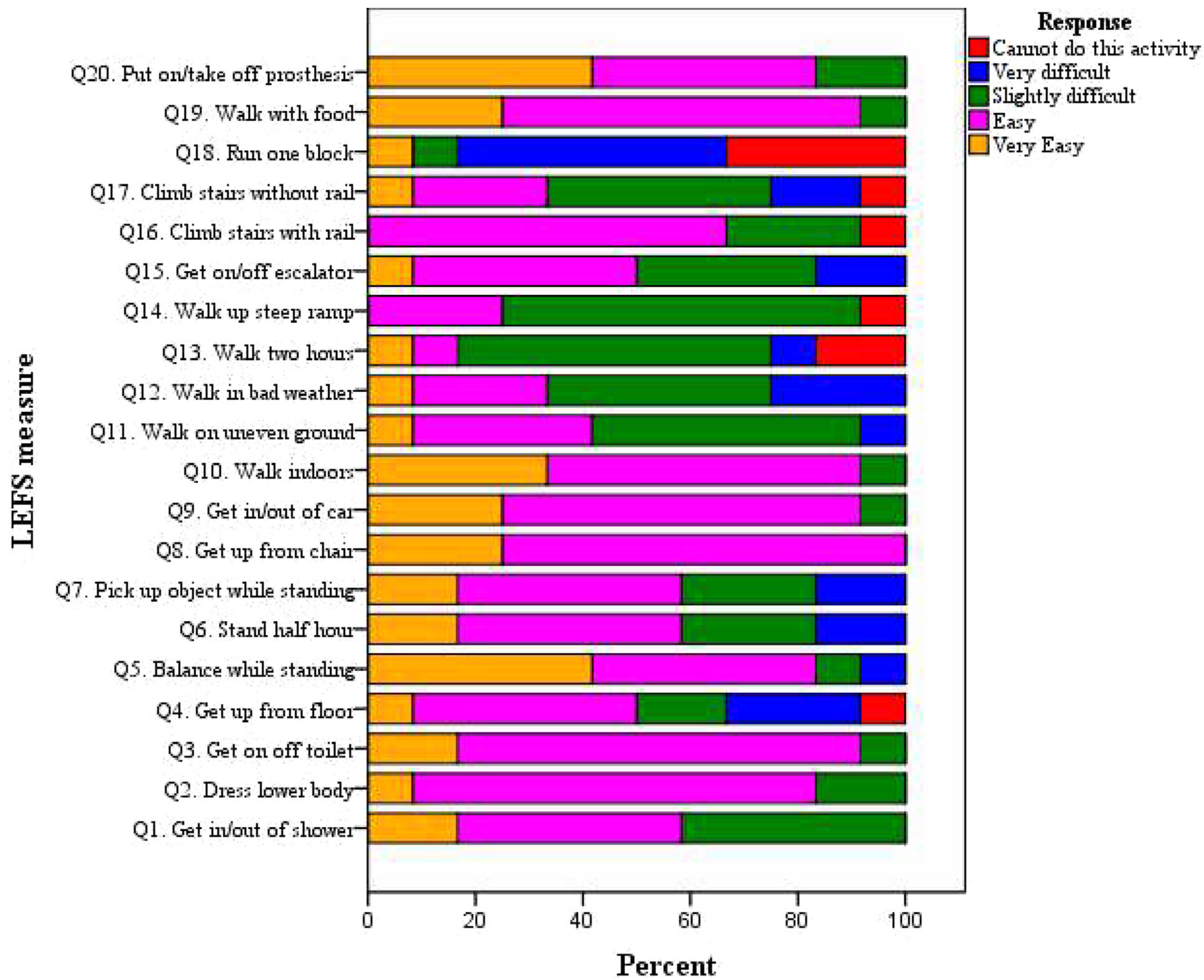

Fig 1 Lower Extremity Functional Status (LEFS). Note: mean distribution of participant responses to the 20-item LEFS (N=12).

test. A simple linear regression was calculated to predict LEFS scores based on TUG test time. A significant regression equation was found, $F_{1,9}$=8.85, P=.016, with an R^2 of .50. Participants' predicted LEFS score was equal to 70.13+ −1.37) (TUG value) when TUG was measured in seconds. For each second of the TUG test, participants' LEFS score decreased by 1.37.

Discussion

This study examined the relationship between how prosthetic clients judge their ability to function using their prosthesis compared with a virtual clinical functional assessment by a clinician. The results suggest lower limb prosthesis users accurately assess their ability to function when compared to the validated TUG assessment. The LEFS outcomes were negatively related to the TUG assessment, suggesting the faster they completed the TUG (fewer seconds to complete and more functional capability), the higher their ability score on the LEFS. Patient self-reported clinical outcome measures such as LEFS are essential for evaluating the physical and functional effect of prostheses.[24,25] In this study, the virtually deployed LEFS reflected the patient experience at home, and this perspective is necessary for shared clinical decision making. Recent studies have demonstrated the usefulness of home-based care as part of cardiac outpatient rehabilitation.[13,14] The current study suggests that the virtual approach to home-based prosthetic rehabilitation assessment may be complementary to clinic-based assessment by providing valuable insights into functional capacity and independence in this population. This virtual method may also be useful to monitor rehabilitation progress and facilitate return to preamputation functional levels.

The results also suggest a virtual clinician-administered assessment can be an accurate evaluation of the functional capability of prosthetic users. The virtually administered TUG test provided a reasonable and clinically relevant assessment regarding patient mobility during basic functional tasks outside the clinic setting. The ease and cost-effectiveness of TUG test administration, combined with the observed correlation with self-reported LEFS measures, enhances the translation to clinical practice.

The participants in this study reported basic activities of daily living such as getting in and out of the shower, walking indoors, getting on and off the toilet, and getting up from a chair as either "very easy" or "easy." These ambulatory and toileting activities are an important part of routine prosthetic client evaluation and help the clinician assess prosthetic rehabilitation.[26] The mean LEFS score of 55.1±4.4

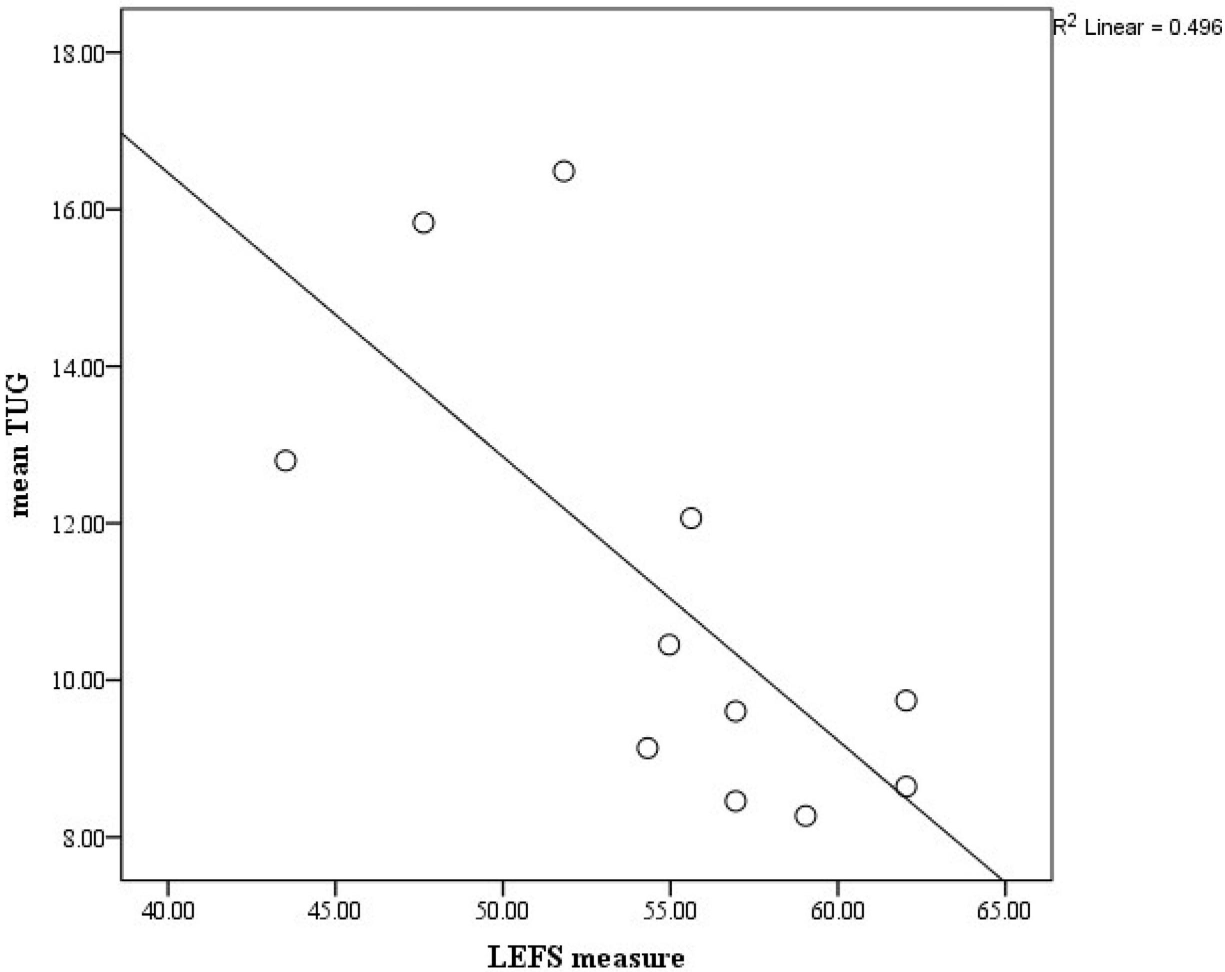

Fig 2 Pearson correlation between investigator-recorded mean TUG test and participant-reported mean LEFS scores.

reported in the current study corresponds to a moderate level of lower extremity physical functioning and is similar to findings in a recent cross-sectional study of Malaysian transfemoral prostheses users (mean 51.53±11.84).[27] Another study in a population of war veterans with combat-related amputation reported a comparable mean LEFS score of 45.7±14.2.[28] These findings suggest both civilian and military populations report basic functional mobility issues in nonclinical environments, which can affect personal care, safety, and independent living.[26]

Participants reported activities requiring greater strength and balance, such as running, walking for longer periods, and walking up a steep ramp, as "very difficult," or "cannot do this activity." These findings are similar to past research in trained service members,[28] a physically inactive cohort of individuals with lower limb amputation,[29] and a mixed population of orthotic and prosthetic clients.[30] This suggests that similarities in self-reported lower extremity function exist between different groups of prostheses users irrespective of physical activity levels. This limitation in performing more strenuous movements with lower limb prosthesis should be explored in subsequent research and inform future device or rehabilitation reviews.

The virtual TUG test scores obtained in the current study revealed that participants had a comparable task completion time to the standard reference range of expected TUG times for unilateral transtibial and transfemoral prostheses users (reference: 12.3±4.5 to 13.0±5.6s).[21] This suggests participants in our study are representative of a broad population of prosthetic users with a higher level of functioning than the general elderly population[31] or among other individuals with unilateral lower limb amputation.[32] This may be because of the younger average age of our population. The outlier excluded from the TUG analysis in the current study is representative of the variance in physical performance among lower limb prosthesis users as seen in clinical practice and is likely the result of the participant becoming accustomed to a new prosthetic.

The virtual clinical mobility test was negatively correlated to how the patients reported their ability to function at home. This significant negative linear association (r=−.70) between the LEFS and the clinician-evaluated mobility test (TUG) has also been demonstrated in other self-reported measures of lower limb function such as the Prosthetic Limb Users Survey of Mobility (r=−.54)[33] and the Activities-specific Balance Confidence Scale (r=−.70).[33] The reports of high levels of balance confidence in all these studies may have a direct effect on these findings. The simple regression calculation further suggests that the clinician-administered TUG test may predict the LEFS score reported by prosthetic patients. To our knowledge, this is the first pilot study to explore the direction, strength of association, and predictive properties of the TUG test on lower extremity function in prostheses users using the LEFS instrument.

By evaluating the time taken to complete various mobility tasks in the home environment under direct observation, clinicians are likely to better gauge the individual's ability to perform daily activities and immediately identify movement limitations or impairments. This information is possibly relevant for informing treatment plans, rehabilitation strategies, and prosthetic interventions tailored to enhance mobility and quality of life for amputees. Additionally, virtual administration of the TUG test potentially offers a convenient and accessible means of assessment, particularly in situations where in-person evaluations may be challenging or impractical. This approach may also give clinicians an impression of their patient's fall risk by providing information on both self-perceived and actual prosthetic mobility. Please see appendix 1 for additional test scores and study data.

Study limitations

The low sample size of this pilot study limits the detection of the true effect, and the cross-sectional design further limits the determination of a causal relationship between functional status with leg prosthesis and the mobility test. Further, we did not adopt progression criteria for the proposed follow-up study. Therefore, the results should be interpreted cautiously. We also did not control for the physical activity profile of participants, and this may introduce an important confounder. Subsequent follow-up studies should involve a larger population of individuals with both unilateral and bilateral lower limb amputations, use wearable technology, and employ the component TUG test to obtain additional clinical information. Gait analysis from the virtual TUG recordings would also be used to provide more clinically meaningful data to further evaluate persistent gait abnormalities with the prostheses.

Conclusions

This study demonstrated the relationship between how prosthetic clients judge their ability to function using their prosthesis compared with a functional mobility assessment conducted by a clinician. Our results suggest that a virtual clinician-administered assessment can be an accurate evaluation of the functional capacity of prosthetic users. Results from this study highlight lower limb prosthesis clients' desire for improved function in activities such as prolonged walking and running. Home-based assessments have the potential to offer practitioners detailed mobility information, serving as a foundation for tailoring intervention programs, rehabilitation plans, and prosthetic training. This approach optimizes patient outcomes and contributes to enhancing quality of life. Further research is needed to explore the feasibility of other physical functioning tests in nonclinical settings in this population of interest.

Suppliers

a. Zoom software; Zoom Video Communications
b. SPSS, version 28; IBM.

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Disclosure

None.

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Authorship Contributions/CRediT statements

Conceptualization, O.D., J.R., A.V., and J.S.; methodology, O.D., J.R., A.V., D.S., and J.S.; data collection, O.D.; data analysis and visualization, O.D.; data interpretation, O.D., J.R., A.V., D.S., and J.S.; manuscript writing — original draft preparation, O.D.; manuscript review and editing, O.D., J. R., A.V., D.S., and J.S.; supervision, J.R., A.V., D.S., and J. S.; project administration, O.D. and J.S.; funding acquisition, J.S. All authors have read and agreed to the published version of the manuscript.

Data statements

Data generated or analyzed during the current study are included in this manuscript and supplementary files.

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