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Original Research

Stump Length and Its Role in Improving Functional Mobility Among Transtibial Prosthesis Users

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ABSTRACT

Background: *Transtibial amputations generally have a better survival prognosis, and the remaining stump length after transtibial amputation (ideally 12-35 cm) plays a crucial role in the functional mobility of prosthesis users, including balance, weight transfer, walking, and daily activities. Mobility limitations can negatively impact the social aspects, quality of life, and health of amputees, making restoring mobility through prosthesis use an important goal. The purpose of this study was to determine and prove to evaluate the contribution of stump length the relationship between stump length and functional mobility in transtibial prosthesis users.*

Methods: *The research method used was quantitative, with an analytical observational study and a cross-sectional design. A total of 15 respondents were selected from a population of 55 below-knee amputee patients using transtibial prostheses using a purposive sampling technique using the L – Test of Functional Mobility instrument.*

Results: *The Spearman Rank Correlation test produced a p-value of <0.001 which is statistically significant with a correlation coefficient of 0.845 which is very strong and positive. So, there is a very strong relationship between stump length and functional mobility in transtibial prosthesis users.*

Conclusion: *The longer the transtibial stump, the better the functional mobility. It is recommended that during amputation the stump be kept as long as possible.*

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KEYWORDS
functional mobility; L–functional mobility test; stump length; transtibial prosthesis; transtibial amputee

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INTRODUCTION

Lower limb amputation is a significant factor affecting quality of life and mortality worldwide. Post-amputation individuals require rehabilitation to gain the ability to walk independently using a prosthesis and adapt their gait patterns to their new physical condition (Marchis et al., 2022). The percentage of lower extremity amputations accounts for 85% of all types of amputations, and the incidence of above-knee and below-knee amputations has a frequency of 64.4% of all lower extremity amputations (Manickum et al., 2019). In the Indonesian context, the need for prosthetic rehabilitation services remains a major challenge due to limited access, high costs and the uneven distribution of specialists across different regions.

The literature describes that people with below-the-knee amputations (transtibial amputations) have a better survival rate than people with above-the-knee amputations because they cause fewer complications (Qaarie, 2023). The most common causes of below-knee amputations in 2020 were trauma (76.3%), vascular disease (19.3%), and congenital heart disease (4.4%) (Bok & Song, 2022). This indicates that the factors leading to amputation have a significant impact on patient prognosis and the success of long-term rehabilitation.

The ideal amputation procedure will maximize the bone length of the remaining part and have a strong soft tissue cushion, good blood circulation, and good sensitivity (Chang & Kleiber, 2023). Ranjan and Pawar (2021) classifies the remaining body part (stump) into 3, namely short, medium, and long. In transtibial amputations, the ideal stump length ranges from 12 cm to 35 cm depending on the individual's height (Kolářová et al., 2021). Referring to research Morgan et al. (2020), individuals with transtibial amputations have limitations in mobility function, reduced endurance, and slower walking speed compared to individuals without amputations.

According to Bouça-Machado et al. (2020), mobility is defined as the ability to move freely and easily. Mobility functions for amputees, such as balancing and shifting body weight, changing direction, turning, pivoting, navigating environmental obstacles, varying walking speeds, and using stairs, require special adjustments to carry out daily tasks and activities (Morgan et al., 2020). Limited mobility can lead to feelings of social isolation, reduce quality of life, and impact on a person's health throughout life. Rehabilitation clinicians often perform physical mobility evaluations to assess patient status, guide the rehabilitation care plan, and inform details of the prosthetic prescription (Morgan et al., 2022).

Physical mobility requires sufficient muscle strength and energy, adequate stability, good joint function, and optimal synchronization of the neuromuskeletal system (Ernstmeyer & Christman, 2024). Research shows that the more ideal the stump length, the less energy expended when walking compared to individuals with a more proximal stump when using a prosthesis (Ranjan & Pawar, 2021). Medically, a more distal tibiofibular cut will create a larger and more stable weight-bearing area by providing greater control over torsional and rotational movements of the prosthesis (Chang & Kleiber, 2023). Therefore, planning the appropriate level of amputation is a key factor in determining the success of prosthetic use and the patient’s mobility following amputation.

Mukkamala and Vala (2024) described a statistically significant relationship between stump length and functional mobility, as demonstrated by longer TUG time results in individuals with more proximal amputations. Longer TUG time results may be influenced by poorer walking distance, slower walking speed, and greater energy expenditure when walking with a prosthesis in individuals with more proximal amputations. This confirms that stump length is a key factor influencing the efficiency and functional mobility of prosthesis users.

Findings from the research Schaik et al. (2019) a total of 61 studies (with a total of 1.912 participants) were included in a systematic review and meta-analysis using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Oxygen consumption was analyzed using predictors such as amputation level, age, and gait speed. Results showed that mean oxygen consumption and heart rate increased by increasing gait speed and more proximal amputation. However, there remains a gap in the research regarding specifically how stump length influences improvements in functional mobility among transtibial prosthesis users; therefore, further study is required.

According to a preliminary study conducted at the Ipoed Prosthetic Leg Clinic between 2022 and 2024, a total of 49 patients were treated with transtibial prostheses. Of these, 9 had short stumps, 33 had medium-sized stumps, and 7 had long stumps. Stump length plays a crucial role in determining post-amputation prescription and rehabilitation, yet it is often overlooked. Although several studies have examined the relationship between amputation level and functional mobility factors, the specific relationship between transtibial stump length and functional mobility has not been thoroughly analyzed. This paper aims to address this gap by addressing several differences in subject criteria, location, and measurement instruments compared to previous studies. So, the purpose of this study was to determine and prove the relationship between stump length and functional mobility in transtibial prosthesis users.

MATERIALS AND METHOD

The study used a cross-sectional design, in which the independent and dependent variables are measured at a single point in time. This study aims to determine and prove the relationship between stump length and functional mobility of transtibial prosthesis users by observing functional mobility abilities using the L – Test of Functional Mobility instrument. In this study, researchers analyzed the relationship between stump length and functional mobility in transtibial prosthesis users using quantitative methods with an analytical observational study type and a cross-sectional design. Analytical research aims to investigate the relationship between one variable and another (Hardani et al., 2020).

The population in this study were all patients with transtibial amputations who used transtibial prostheses from the clinic at IPOED Kaki Palsu dan Ortho Syam during February to March 2025. The sample in this study were transtibial prosthesis users with long, medium, and short stumps who met the inclusion and exclusion criteria determined based on the research objectives (purposive sampling). A purposive sampling approach was used to ensure that the research subjects selected truly met the established criteria.

The inclusion criteria in this study were patients with unilateral amputations, aged 19-44 years, who had used the prosthesis for more than 1 year, and patients who used a foot with a solid ankle cushion heel (SACH foot). By providing good shock absorption, the SACH Foot is able to reduce stump pressure during mobility (Balaramakrishnan et al., 2020). The exclusion criteria for this study were subjects in poor health, pain, edema, stump injuries, and subjects using assistive devices other than prostheses. Fifteen respondents were selected from a population of 55 below-knee amputee patients using transtibial prostheses to participate in this study. This sample was obtained based on screening of the established inclusion and exclusion criteria.

The instrument used in this study was the midline to measure stump length, measured from the patellar tendon to the tip of the stump. Functional mobility was measured using the L-test, the duration of which was calculated using a stopwatch. A digital stopwatch was used to record time and distance, measured in meters (Balbi et al., 2021). All measurements were carried out following standardized procedures to ensure accuracy and consistency of the data.

Based on the trajectory image above, the researcher determined the starting point (start timing) to take a distance of 3 meters. Then, from the 3-meter distance point, the researcher measured a distance of 7 meters (end timing) to the right or left as a turning angle to form an "L" configuration. The researcher asked the subject to sit on a chair that had been provided. Then, he was instructed to stand up and walk along the trajectory until he sat back down on the same chair. The duration was measured from the subject getting

up from the chair, crossing the letter "L", until he sat back down. The test was conducted on a flat area (road, field, home area) and was carried out 3 times with short breaks to minimize significant increases, then the average was calculated.

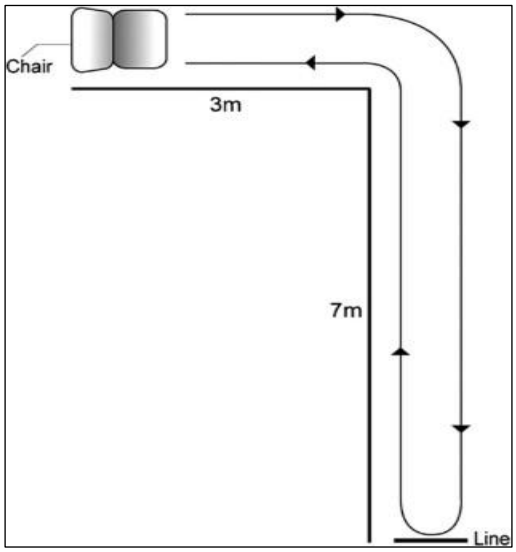


Figure 1. L - Test of Functional Mobility
Source: Sions (2019a)

The dependent variable in this study was functional mobility, and the independent variable was transtibial stump length. The Shapiro-Wilk test was used for normality because the sample size was less than 50 respondents. The hypothesis test used to process this study was Spearman Rank/Non-Parametric correlation analysis.

This research was approved by the ethics committee of Dr. Moewardi Hospital, Surakarta, on February 18, 2025, with the number 351/II/HREC/2025. In its implementation, this research also applies the ethical principles of health research, including respecting subject autonomy, maintaining data confidentiality, ensuring participant safety, and ensuring that all procedures are carried out in accordance with applicable ethical standards.

RESULTS

This study will examine the correlation between stump length and functional mobility in transtibial prosthesis users at the Ipoed Prosthetic Leg Clinic and the Ortho Syam Clinic. The research report presents respondents' demographic characteristics, data normality test results, and correlation test results, including variables such as gender, age, cause of amputation, duration of prosthesis use, and stump length category, while excluding anthropometric data such as weight and height. The results are presented in a frequency distribution table based on gender and age.

Table 1. Subject characteristics based on gender and age (n = 15)

Variable		Frequency (n)	Percentage (%)
Gender	Man	13	86.7
	Woman	2	13.3
	Total	**15**	**100**

Variable		Frequency (n)	Percentage (%)
Age	Early adulthood (18-40 years)	8	53.3
	Middle adulthood (40-60 years)	7	46.6
	Late adulthood (over 60 years)	0	0
	Total	**15**	**100**

The largest number of respondents were men, 13 out of a total of 15. Men reported experiencing amputations more frequently than women and were more frequently involved in high-risk occupations or activities (Julien et al., 2021). The above data shows the age distribution of adult respondents (19-44 years old), who are considered to be within the productive age range for mobility, based on Regulation of the Minister of Health of the Republic of Indonesia No. 25 of 2016 concerning the National Action Plan for Elderly Health. The age distribution of respondents in this data is quite diverse, with an age range of 22 to 44 years. The average age of the subjects in this study was around 36 years old.

The next respondent characteristic is based on the cause of amputation length of prosthesis use, and stump length. Based on the data obtained, the following frequency distribution table are:

Table 2. Characteristics of subjects based on the cause of amputation, length of prosthesis use, stump length (n = 15)

Variable	Category	Frequancy (n)	Percentage (%)
Causes of Amputation	Trauma	11	73.3
	Congenital	4	26.7
	Total	**15**	**100**
Duration of Prosthesis Use	13 years old	2	13.3
	4 – 7 years	5	33.3
	>8 years	8	53.3
	Total	**15**	**100**
Stump Length	4	4	26.7
	7	7	46.7
	4	4	26.7
	Total	**15**	**100**

Researchers focused solely on causes of amputation due to trauma and congenital causes. Traumatic amputation was a more dominant factor in this data (11 respondents) compared to congenital amputation (4 respondents). According to interviews during data collection, the majority of study subjects were individuals with amputations with a history of confirmed causes of amputation as a traffic accident. Researchers also categorized the subjects based on the length of time they had used their prosthesis.

In the study Bokan (2024) the duration of prosthesis use was categorized into three categories: short use (1-3 years), moderate use (4-7 years), and long use (>8 years). The history of amputation varied among respondents, with the shortest use being 2 years and the longest history being 30 years of prosthesis use. The average history of prosthesis use in this study was 10.47 years. The longer a person uses a prosthesis, the better their adaptation and functional abilities tend to be (Mukkamala & Vala, 2024).

The medium length category was the most common, accounting for nearly half of all respondents. The long and short stump length categories were equally frequent, each contributing more than a quarter of the total data. From the data obtained, the following frequency distribution table is provided based on stump length and average functional mobility test results:

Table 3. Subject characteristics based on stump length with functional mobility (n = 15)

Stump Length	Frequncy (n)	Mean Mobility Functional
Long	4	24.57
Medium	7	25.55
Short	4	27.37

The data grouped the stump length variable into three categories: long, medium, and short. Based on the average L-Test results, shorter stump lengths were associated with higher functional mobility test times (27.37 seconds for short stumps compared to 25.55 seconds for medium stumps and 24.57 seconds for long stumps). This suggests that the shorter the residual limb, the lower the functional mobility of the prosthesis user.

After collecting data on the characteristics of the research sample, a hypothesis test was conducted to determine data normality. The Shapiro-Wilk test was used because the sample size for this study was less than 50 respondents. Stump length had a significance level of 0.007 (p-value <0.05), with normality test results indicating that the data distribution for this variable was not normal. The normality test results for the functional mobility variable showed that the data were normally distributed with a significance level of 0.330 (p-value >0.05). From the distribution of data for each variable, it can be concluded that the data were not normally distributed.

The hypothesis test used to process this research was Spearman Rank/Non-Parametric correlation analysis because the data was not normally distributed. The rule used to determine the relationship between the two variables is that if the p-value < 0.05, it is stated that there is a relationship between the two variables. If the p-value > 0.05, it means there is no relationship between the two variables.

Table 4. Hypothesis Testing of the Relationship between Stump Length and Functional Mobility (n =15)

Variable	Correlation Coefficient (r)	Significance (p-value*)
Stump length vs Functional Mobility	0.845	<0.001

Note: * Spearman Rank/Non-Parametric correlation analysis

Based on the hypothesis test data that has been conducted, the variable of stump length with functional mobility variable has a significance p value of 0.000 and a correlation coefficient of 0.845 with a positive relationship. The correlation coefficient indicates a very strong level of relationship strength. A positive relationship states that the longer the stump, the higher the functional mobility ability.

In the book "Quantitative, Qualitative, and R&D Research Methods" by Sugiyono (2023), a coefficient value of 0.00-0.199 indicates a very low level of relationship, a coefficient value of 0.20-0.399 indicates a low level of correlation, a coefficient value of 0.40-0.599 indicates a moderate level of correlation, a coefficient value of 0.60-0.799 indicates a strong level of relationship, and a coefficient value of 0.80-1.000 indicates a

very strong level of relationship. This study can be concluded that there is a strong relationship between stump length and functional mobility in transtibial prosthesis users ($p < 0.05$) with a positive relationship.

DISCUSSION

This study aimed to determine the relationship between stump length and functional mobility in transtibial prosthesis users. This study was conducted on subjects with transtibial amputations who used transtibial prostheses. The subjects in this study were patients from 2 different clinics, namely the Ipoed Prosthetic Leg Clinic and the Ortho Syam Clinic with a total number of subjects according to the criteria of 15 people. The study was conducted by visiting the subjects' homes in February - March 2025. Based on the characteristics of the research data, the largest percentage of transtibial prosthesis users in this study were the majority of men compared to women (Clemens et al., 2024) he stated that, in general, men tend to have better physical performance than women. This results in men's walking ability being faster than women's.

All respondents in this study were in the adult age range, namely from 22 to 44 years old. Based on Regulation of the Minister of Health of the Republic of Indonesia No. 25 of 2016 The National Action Plan for Elderly Health is divided into age categories, namely neonatal and infant (0-1 year); toddler (1-5 years); preschool children (5-6 years); children (6-10 years); adolescents (10-18 years); adults (19-44 years); pre-elderly (45-59 years); and elderly (≥60 years). Veronese et al. (2022) stated that individuals in younger age groups generally show slower performance in mobility tasks, compared to adults. This occurs due to ongoing physical growth, which causes changes in strength, agility, and stamina.

The most common cause of amputation in this study was trauma, with 11 respondents reporting it, and 4 others were due to congenital diseases. According to (Seth et al., 2022) the cause of amputation affects an individual's health and adaptability. Individuals with amputations due to vascular disease often have poorer health. Meanwhile, those with traumatic amputations are typically younger and healthier, have higher initial activity levels, and adapt well. Furthermore, adapting to a prosthesis from an early age in individuals with congenital amputations often contributes to improved mobility.

The history of prosthesis use was grouped into three categories: short use (1-3 years), moderate use (4-7 years), and long use (>8 years). In general, patients with transtibial prostheses demonstrated a good quality of life across all three categories (Bokan, 2024). In this study, the highest frequency category of stump length was medium stump. According to Chui et al. (2019), the length of the stump is grouped into 3 categories, namely: (1) Long stump, if the tibia and fibula are <35% long, (2) Medium stump, if the tibia and fibula are 35% - 50% long, (3) Short stump, if the tibia and fibula are >50% long. According to Chang and Kleiber (2023) a longer stump provides a better lever arm on the tibia for optimal prosthesis placement, allowing the patient to walk more efficiently with less energy expenditure. Meanwhile, the frequency of contractures is higher at the amputation level with a shorter stump length due to the loss of knee joint stabilization by the larger gastrocnemius-soleus muscles (Demir & Aydemir, 2021).

This study used the L-Functional Mobility Test to measure the functional mobility abilities of the respondents. This test measures the time it takes a person to get up from an armless chair, walk 3 m, make a 90-degree turn to the right or left, and continue walking 7 m before turning 180 degrees, then walk back along the same path to sit down,

recorded in seconds (Frangakis et al., 2024). Subjects were asked to perform the test at their normal speed three times with short breaks to minimize significant increases, and then averaged. The shorter the L-Test completion time, the better their functional mobility.

The group with a long stump length (4 respondents) had an average functional mobility of 24.57 seconds. The medium stump category had a frequency of 7 respondents with an average functional mobility of 25.55 seconds. Furthermore, the short stump group with 4 respondents had the highest average functional mobility test time, namely 27.37 seconds. The difference in time produced by the long stump group with the medium stump group was 0.98 seconds, the medium stump group with the short stump group was 1.82 seconds, and the difference between the long stump group and the short stump group was 2.8 seconds. From this analysis, the functional mobility test in the long stump group had the lowest functional mobility time results. The faster the test is completed, the better the functional mobility.

Referring to research Seth et al. (2022) the reference value for completing the L-Test for individuals with unilateral transtibial amputations is 29.5 seconds. Research conducted by researchers on the long, medium, and short stump groups showed that the L-Test completion times for all three categories were above this reference value. Therefore, all three stump level categories in individuals with unilateral transtibial amputations in this study demonstrated good levels of functional mobility.

The results of data processing based on the Spearman rank correlation test output show that there is a relationship between stump length and functional mobility. The correlation coefficient number between the stump length variable and the functional mobility variable is 0.845, meaning the level of relationship between the variables is very strong with a positive relationship. Thus, it can be interpreted that the longer the amputation stump length, the higher the functional mobility.



Figure 2. User with Long Stump

The results of this study are consistent with research conducted by Mukkamala and Vala (2024), which stated that the shorter the stump, the longer it takes to complete the TUG test, indicating decreased functional mobility. This is influenced by factors such as difficulty maintaining balance while standing, gait asymmetry, imbalanced muscle strength, and increased energy consumption for mobility in individuals with shorter stumps. Individuals with longer stumps have better stride length and walking speed than those with shorter stumps.

In line with the findings Sawers and Fatone (2025) amputations at a more distal level are associated with better walking energy efficiency, allowing for faster walking speeds and greater walking endurance than amputations at a more proximal level. Shorter stump lengths impair the thigh muscles' ability to efficiently control the prosthesis during daily activities, such as standing and walking. As muscle strength decreases, a person's stride length becomes shorter, which is closely related to the decreased ability of the muscles around the knee and hip to propel the body forward.

Individuals with more proximal amputations experience decreased balance. Posture often shows a tendency to tilt toward the non-amputated side. This is evident by a shift in the average position of the center of pressure and its movement toward that side. This postural change is a compensatory mechanism to maintain balance and stability. This may be due to the reduction in active muscle tone that occurs at more proximal amputations (Toumi et al., 2021).

The ability of transtibial amputees to generate muscle force, both isokinetic and isometric, is significantly reduced if the stump is less than 15.1 cm long. The percentage of muscle in a short stump influences changes in muscle fiber length, muscle composition, and muscle activation levels, thereby reducing muscle strength in the stump. Lower muscle strength impacts mobility and health. Muscle strength deficits are associated with gait changes, decreased energy efficiency and walking endurance, changes in joint loading, and the risk of osteoarthritis and low back pain (Hewson et al., 2020).

As the tibia length decreases toward the tibial tuberosity, the knee flexors gain mechanical advantage over the knee extensors. Consequently, full knee extension during the swing phase of gait and knee extension stability in the early midstance phase become more difficult. A longer stump allows for better pressure distribution within the prosthesis socket and provides a longer lever arm, potentially increasing the user's control over the prosthesis (Chui et al., 2019).

In addition to stump length, functional mobility can also be affected by the length of time the prosthesis is used. Based on research from (Mukkamala & Vala, 2024) prostheses increase walking independence, and the longer a person uses them, the greater the opportunity for physical and psychological adaptation. Physical adaptation involves strengthening and improving coordination of body movements. Psychological adaptation includes self-acceptance and increased self-confidence. The ability to accommodate these changes will improve overall mobility.

The implications of this research are to provide information and benefit to medical personnel, particularly orthotists and prosthetics, that different stump lengths will impact the functional mobility of the study subjects. The longer the stump, the better the patient's functional mobility. These findings can serve as a basis for consideration in rehabilitation planning and prosthesis design to improve patients' mobility.

The limitations and weaknesses of this research that can influence the results of this research are: (1) Role factors that can influence walking mobility such as the activity level

of each subject (K-Level); (2) Unequal proportions between the number of short, medium, and long stumps; (3) not carrying out standard coding regarding the standardization of rest time per session break; (4) The terrain in the research is not uniform and depends on the respondent's environment; and (5) The number of respondents who meet the inclusion criteria is very limited and some cannot be contacted. Based on the research results and discussions that have been presented, the following are several suggestions for further research, namely: (1) Specify the K-Level of respondents; (2) The number of respondents is balanced between short, medium, and long stumps; (3) The standardized rest time needs to be the same between subjects; (4) Try to carry out L-Functional Mobility Test measurements in one place with a flat area for all subjects; and (5) Reach more rehabilitation centers, communities, or hospitals to expand the research reach and increase the number of samples.

CONCLUSION

The findings indicate that longer transtibial stump length is associated with better functional mobility outcomes. These results highlight that stump length plays an important role in determining post-prosthetic functional performance. Furthermore, the findings provide valuable implications for orthotists and prosthetists in clinical practice, as well as for surgical decision-making in determining optimal stump length to achieve improved functional mobility after prosthesis use.

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DECLARATION OF USE OF AI IN SCIENTIFIC WRITING

AI tools were used solely for grammar and language editing. The authors take full responsibility for the content and integrity of the manuscript.

CONFLICT OF INTERESTS

The authors declare that they have no financial or non-financial conflicts of interest that may have influenced the findings of this study.

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