

Original Research

Does Body Mass Index Matter? Static Balance in Transfemoral Prosthesis Users

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ABSTRACT

Background: Body Mass Index (BMI) is an important indicator in assessing an individual's nutritional status and may influence body balance, particularly in individuals with transfemoral (above-knee) amputation using a prosthesis. Postural imbalance in prosthesis users can disrupt mobility and increase the risk of falls. This research aimed to determine the relationship between Body Mass Index and static balance in users of transfemoral prosthesis.

Methods: This study employed a quantitative approach with a cross-sectional design and purposive sampling technique. The study involved 15 subjects who met the inclusion criteria. BMI was calculated based on body weight and height, while static balance was assessed using the Romberg Test. Normality was tested using the Shapiro-Wilk test, and hypothesis testing was conducted using Spearman correlation due to non-normal data distribution.

Results: The analysis showed a significant relationship between BMI and static balance, with a correlation coefficient of 0.687 and a significance value of 0.005 ($p < 0.05$). This indicates that a higher BMI is associated with greater impairment in static balance among transfemoral prosthesis users.

Conclusion: There is a significant relationship between body mass index and static balance in transfemoral prosthesis users. Weight management plays a crucial role in the rehabilitation process to improve balance and quality of life in individuals with lower-limb amputation.

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INTRODUCTION

Dividing body weight (kg) by squared height (m²) yields the body mass index (BMI), a simple screening measure of adult nutritional status that the World Health Organization endorses for detecting overweight and obesity (World Health Organization, 2021). Because Asian populations accumulate metabolic risk at lower BMI values, Asia-Pacific thresholds are set lower: 18.5–22.9 kg/m² is normal, 23–24.9 kg/m² overweight, and 25 kg/m² or higher obese. A person's BMI at any moment

reflects long-term energy balance, which diet, physical activity, genetic, epigenetic, and environmental influences jointly determine (Lin & Li, 2021).

Amputation is often followed by weight gain. In a Dutch survey, obesity was more prevalent among people with a lower limb amputation than in the general adult population (Mollee et al., 2021), which may reflect reduced mobility and activity. Amputation between the hip and knee (transfemoral level) sacrifices the knee joint and part of the thigh muscles and markedly reduces lower-extremity function (Heitzmann et al., 2020). Wearers of lower limb prostheses frequently have trouble with balance and postural control, and over half report at least one fall per year (Kim et al., 2022; Rusaw et al., 2021).

Balance is the ability to hold the center of mass above the base of support; it draws on visual, vestibular, and somatosensory information and on appropriate muscle responses. Standing quietly with minimal deviation from the intended posture is an example of static balance. Stability during walking, running, or any other movement that shifts the base of support is called dynamic balance. Static tasks are informative in prosthesis wearers because they rely on vision more heavily than non-amputees, and disturbing visual input degrades their postural control (Fuchs et al., 2021). Balance is also influenced by the center of gravity (COG), the line of gravity (LOG), the extent of the base of support (BOS), and BMI (Almurdi, 2024; Bochenek et al., 2024).

Outside the amputee population, several reports tie a higher BMI or adiposity to poorer postural stability. Cimolin et al. (2020), in a narrative review, described diminished balance control in obese people during quiet standing; obese adults awaiting bariatric surgery showed greater anteroposterior sway than non-obese adults, eyes closed included (Pagnotti et al., 2020); young female students with higher BMI and body-composition values had poorer postural balance (Almurdi, 2024); and (Handayani et al., 2022) concluded that balance ability deteriorates as BMI rises. Not every study agrees, though: among 624 asymptomatic adults older than 40, the weak-to-moderate associations between obesity indices and static balance were no longer significant after confounder adjustment (Ostolin et al., 2020).

Evidence for amputees is sparser and mostly indirect. Severely obese patients (BMI > 40 kg/m²) had lower functional scores at discharge from inpatient amputation rehabilitation (Dubin et al., 2025), and a higher BMI in transfemoral prosthesis wearers went with self-reported difficulty in daily activities such as walking between rooms, squatting, and heavy tasks (Shafiq et al., 2023). To our knowledge, the link between BMI and static balance has not been examined specifically in transfemoral prosthesis wearers, and Indonesian data are particularly lacking. This group is biomechanically distinct from transtibial wearers: with the knee joint absent, more of the thigh musculature lost, and pronounced hip weakness in the residual limb, load distribution and postural control are altered in a more intricate fashion (Heitzmann et al., 2020; Hewson et al., 2020).

The novelty of this study lies in three aspects. It is confined to unilateral transfemoral cases, who are rarely studied in BMI–balance research; it assesses balance with the prosthesis worn and the eyes closed, which takes away the visual compensation these individuals rely on (Fuchs et al., 2021a), using the Romberg test, a quick procedure feasible in clinics without laboratory equipment; and it supplies preliminary Indonesian data interpreted against Asia-Pacific BMI cut-offs. The purpose was to determine whether BMI is associated with static balance among transfemoral prosthesis wearers in Solo and surrounding areas. This study contributes to providing preliminary

data on the relationship between BMI and static balance in users of unilateral transfemoral prostheses in Indonesia, which can serve as a foundation for further research and the development of clinical assessments in prosthetic rehabilitation.

MATERIALS AND METHOD

Study Design and Participant

This was an observational cross-sectional study carried out in January–February 2025 in orthotic and prosthetic clinics and among community groups of transfemoral prosthesis wearers in Surakarta and neighboring areas of Central Java, Indonesia. A cross-sectional design was chosen because this study aims to identify the relationship between BMI and static balance over a single observation period without providing any intervention to the participants. This design allows for the simultaneous measurement of variables in transfemoral prosthesis users under real-world clinical conditions, making it suitable for obtaining an initial understanding of the relationship between these two variables.

Participants were transfemoral prosthesis wearers living in that area, selected by purposive sampling; 15 met the eligibility requirements and were included. To be included, individuals needed a unilateral transfemoral amputation, an exoskeletal transfemoral prosthesis used for at least three weeks, good general health, willingness to participate, and residence in Solo or its surroundings. Those who used crutches, canes, or other aids during testing, refused consent, or lived outside Central Java Province were excluded.

Research Variables and Operational Definitions

Independent variable. BMI (body weight in kg divided by squared height in m²) was the independent variable. Both measurements were taken without the prosthesis, using a digital scale and a microtoise. BMI was kept as a ratio-scale value (kg/m²) and additionally grouped into underweight, normal, overweight, obesity I, and obesity II for description. The dependent variable was static balance: the ability to stand upright with the prosthesis on, feet together, arms folded on the chest, and eyes closed for 30 seconds, without losing balance or swaying markedly. It was scored dichotomously (nominal scale) on the Romberg test as negative (balance kept for ≥ 30 seconds; coded 0) or positive (balance lost or marked sway before 30 seconds, that is, impaired static balance; coded 1).

Measurement Instruments and Procedures

Body Mass Index Measurement. Participants were weighed and measured (digital scale, microtoise) before putting on the prosthesis, and BMI was calculated as follows:

$$\text{BMI} = \text{Body Weight (kg)} / \text{Height (m}^2\text{)}$$

The results were grouped according to the WHO Asia-Pacific classification (World Health Organization et al., 2000): (1) Underweight: <18.5 kg/m²; (2) Normal: 18.5–22.9 kg/m²; (3) Overweight: 23.0–24.9 kg/m²; (4) Obesity I: 25.0–29.9 kg/m²; and (5) Obesity II: ≥ 30 kg/m².

Static Balance Measurement: The Romberg test was timed with a stopwatch. With the prosthesis attached, the participant stood upright with feet together and arms folded across the chest, looked forward, and then closed the eyes; timing began at eye closure

and lasted 30 seconds. Keeping balance for the full 30 seconds was scored negative, whereas loss of balance or evident swaying before then was scored positive (Sartika et al., 2025).

Data Analysis

Data were processed with IBM SPSS Statistics version 25 and summarized descriptively. Normality was checked with the Shapiro-Wilk test. Since neither variable was normally distributed, Spearman's rank correlation tested the BMI–static balance association (significance level, $p < 0.05$). The correlation coefficient (r_s) was used to determine the direction and strength of the association between BMI and static balance.

Ethical Considerations

Approval was granted by the Health Research Ethics Commission of Dr. Moewardi Regional Hospital (No. 2.832/XII/HREC/2024), and the Declaration of Helsinki was followed. Written informed consent was obtained before data collection; participants were told the objectives, procedures, risks, and benefits of the study and that taking part was voluntary, and their confidentiality and anonymity were maintained. Participants were informed of their right to withdraw from the study at any time without penalty or consequences for their access to health services.

RESULTS

Characteristics of Participants

Table 1 displays the characteristics of the participants. A total of 15 transfemoral prosthesis users participated in this study. Participants ranged in age from 21 to 59 years. Nine participants (60%) were male, and six participants (40%) were female. BMI values span all categories, with normal weight most frequently (40.0%), then underweight (26.7%), obesity I (20.0%), overweight (6.7%), and obesity II (6.7%). Twelve participants (80%) had a negative Romberg test, meaning intact balance, whereas three (20%) tested positive, meaning impaired balance.

Table 1. Characteristics of Participants (n = 15)

Variables	Category	Frequency (n)	Percentage (%)
Gender	Male	9	60
	Female	6	40
BMI	Underweight	4	26,7
	Normal	6	40
	Overweight	1	6,7
	Obesity	3	20
	Obesity II	1	6,7
Static Balance	Negative	12	80
	Postive	3	20

Normality Test

Neither BMI (Shapiro-Wilk $p = 0.022$) nor static balance ($p < 0.001$) was normally distributed (Table 2), so a Spearman correlation was used.

Table 2. Shapiro-Wilk Normality Test Results

Variable	Statistic	df	p-value
BMI	0.858	15	0.022
Static Balance	0,499	15	<0.001

Hypothesis Test

BMI and static balance were significantly, positively, and strongly correlated ($r = 0.687$; $p = 0.005$; Table 3). Because a positive Romberg test was coded 1, the positive coefficient means that participants with a higher BMI more often had impaired static balance (Table 3).

Table 3. Spearman Rank Correlation Test Results ($n = 15$)

Variables		BMI	Static Balance
BMI	Correlation	1.000	0.687
	Coefficient		
	p-value	-	0.005
Static Balance	Correlation	0.687	1.000
	Coefficient		
	p-value	0.005	-

DISCUSSION

A higher BMI went hand in hand with a positive Romberg test ($r = 0.687$; $p = 0.005$), so heavier participants had more trouble standing steadily with their eyes shut while wearing the prosthesis. Two mechanisms are plausible. The first is mechanical: extra body mass enlarges the load that postural control must counteract. Obese adults show larger anteroposterior sway than non-obese adults in quiet stance, even without vision (Pagnotti et al., 2020), and a narrative review reached a similar conclusion about reduced balance control (Cimolin et al., 2020).

In above-knee amputation this load falls on an already unusual weight distribution, since the knee and part of the thigh muscles are missing and the hip muscles of the residual limb tend to be weak (Heitzmann et al., 2020; Hewson et al., 2020). Hip muscles partly compensate for lost knee and ankle function and contribute to walking and standing balance (Sawers & Fatone, 2022), and once hip strength is scaled to body size, hip abductor strength relates to balance in experienced prosthesis wearers (Sawers & Fatone, 2022). A greater BMI may therefore tax the hip muscles that stabilize the pelvis. This additional mechanical demand may increase postural control requirements and potentially challenge the ability of transfemoral prosthesis users to maintain stable standing.

The second mechanism is sensory. Prosthesis wearers use vision more than non-amputees to stay upright and interfering with it disrupts their posture (Fuchs et al., 2021). Diminished sensory feedback and muscle control in the missing limb have been cited as a principal reason for compromised postural control after transtibial amputation (Kolářová et al., 2021); a comparable loss of afferent input seems likely at the transfemoral level. With the eyes closed, these individuals have little sensory reserve to cope with the extra mechanical demand of a high BMI, which could explain why the association emerged in this test.

The direction of the finding agrees with previous work. Poorer postural balance accompanied higher BMI and body-composition values in young women (Almurdi,

2024). Handayani et al. (2022) also reported that balance worsened with higher BMI. In amputees, severe obesity ($\text{BMI} > 40 \text{ kg/m}^2$) was linked to lower functional scores at rehabilitation discharge (Dubin et al., 2025), and among transfemoral prosthesis wearers a higher BMI was associated with difficulty walking between rooms, squatting, and heavy activities (Shafiq et al., 2023). An earlier Indonesian study of transtibial prosthesis wearers likewise found that BMI correlated with static balance ($r = -0.646$; $p = 0.009$), with normal-BMI participants outperforming underweight and overweight ones (Rachmat et al., 2017); the opposite sign presumably reflects a scale on which higher values meant better balance, whereas here a positive Romberg test means impairment.

Findings are not uniform, however. In adults over 40 without symptoms, the weak-to-moderate associations between obesity indices and static balance vanished after adjustment for confounders (Ostolin et al., 2020), implying that age, sex, muscle capacity, and comorbidity may confound the BMI–balance link; as none was controlled here, our association should be interpreted cautiously. John et al. (2022) compared residual-limb hip strength and force-plate static balance (eyes open and closed) across K-levels in a small preliminary sample of transfemoral wearers and found no significant differences, suggesting that functional classification alone does not explain static balance and that factors such as body mass merit attention. These findings suggest that the relationship between BMI and static balance is likely multifactorial; therefore, future studies should consider anthropometric factors, muscle strength, prosthesis usage characteristics, and clinical conditions simultaneously.

Implications for practice. The results suggest three practical steps. BMI is quick and inexpensive to obtain and could be recorded routinely in prosthetic clinics to identify transfemoral wearers who need a closer balance assessment. Rehabilitation for those with a higher BMI should combine balance training, hip and core strengthening, and weight management; a meta-analysis found that targeted exercise beat conventional prosthetic training for walking speed and distance over conventional prosthetic training, although evidence on balance was inconsistent (Abou et al., 2022). Since weight gain after amputation is common (Mollee et al., 2021), weight monitoring and lifestyle advice should begin early and may also reduce the fall risk that prosthesis wearers frequently report (Kim et al., 2022; Rusaw et al., 2021).

Strengths include the focus on an understudied group, measured rather than self-reported weight and height, testing with the prosthesis worn as in daily life, and a test that is inexpensive, quick, and clinic friendly. The limitations are as follows. The sample was small ($n = 15$), purposive, and drawn from one region, restricting power, the precision of the coefficient, and generalizability, so the results are preliminary. The cross-sectional design precludes causal inference, and poor balance could itself lower activity and promote weight gain. A dichotomous Romberg outcome gives limited resolution and cannot express the size of a deficit, unlike instrumented posturography. BMI was calculated from measured weight without correcting for the missing limb segment, which may underestimate it after transfemoral amputation (Dubin et al., 2025), used limb-adjusted BMI), and BMI does not separate fat from muscle although body composition relates to balance (Almurdi, 2024). Finally, age, sex, time since amputation, cause of amputation, K-level, stump length, prosthetic components, and muscle strength were not controlled.

Larger multicenter studies with an a priori sample-size calculation are needed to confirm these preliminary results. They should quantify static balance continuously (for

example, force-plate posturography with eyes open and closed), model confounders in multivariable analyses, use limb-adjusted BMI plus body-composition measures such as bioelectrical impedance and waist circumference, and add dynamic balance and fall history. Longitudinal or interventional studies should test whether weight management combined with balance and hip-strengthening exercise improves balance in overweight transfemoral prosthesis wearers.

CONCLUSION

In this sample, BMI was significantly associated with static balance among transfemoral prosthesis wearers. A higher BMI corresponded to poorer static balance, so an optimal body weight deserves a place in rehabilitation for above-knee amputees, where it may improve balance and reduce falls. Clinically, these findings highlight the importance of considering BMI status as one component of the assessment and rehabilitation planning for transfemoral prosthesis users, along with balance training and muscle strengthening to support postural control. Larger studies with instrumented balance measures and confounder control are required to verify this.

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DECLARATION OF USE OF AI IN SCIENTIFIC WRITING

The authors reviewed and verified all AI-assisted content and remain fully responsible for the accuracy, originality, interpretation, and final content of the manuscript. AI tools were not used to generate, analyze, or interpret the study data or to make scientific conclusions.

CONFLICT OF INTERESTS

The author declares that there is no conflict of interest in this research.

REFERENCES

- Abou, L., Fliflet, A., Zhao, L., Du, Y., & Rice, L. (2022). The effectiveness of exercise interventions to improve gait and balance in individuals with lower limb amputations: A systematic review and meta-analysis. *Clinical Rehabilitation*, 36(7), 857–872. <https://doi.org/10.1177/02692155221086204>
- Almurdi, M. M. (2024). Postural balance and functional mobility in relation to bmi and body composition among female students at a college of applied medical sciences: A cross-sectional study. *Clinics*, 79, 100401. <https://doi.org/10.1016/j.clinsp.2024.100401>
- Bochenek, M., Sacewicz, T., & Cieśliński, I. (2024). Differences in balance ability between female dancers and active non-dancers. *Polish Journal of Sport and Tourism*, 31(4), 3–8. <https://doi.org/10.2478/pjst-2024-0021>

- Cimolin, V., Cau, N., Galli, M., & Capodaglio, P. (2020). Balance control in obese subjects during quiet stance: A state-of-the-art. *Applied Sciences*, 10(5), 1842. <https://doi.org/10.3390/app10051842>
- Dubin, A., Zarreii, P., Sharififar, S., Nixon, R. M., Conic, R. R. Z., Pendem, K., & Vincent, H. K. (2025). The impact of body mass index on rehabilitation outcomes after lower limb amputation. *PM&R*, 17(5), 539–547. <https://doi.org/10.1002/pmrj.13292>
- Fuchs, K., Krauskopf, T., Lauck, T. B., Klein, L., Mueller, M., Herget, G. W., Von Tschanner, V., Stutzig, N., Stieglitz, T., & Pasluosta, C. (2021). Influence of augmented visual feedback on balance control in unilateral transfemoral amputees. *Frontiers in Neuroscience*, 15. <https://doi.org/10.3389/fnins.2021.727527>
- Handayani, M., Sayuti, M., & Nadira, C. S. (2022). Relationship between body mass index and postural balance among students of the martial arts club at Malikussaleh University. *Diponegoro Medical Journal (Jurnal Kedokteran Diponegoro)*, 11(3), 131–137. <https://doi.org/10.14710/dmj.v11i3.33916>
- Heitzmann, D. W. W., Leboucher, J., Block, J., Günther, M., Putz, C., Götze, M., Wolf, S. I., & Alimusaj, M. (2020). The influence of hip muscle strength on gait in individuals with a unilateral transfemoral amputation. *PLOS ONE*, 15(9), e0238093. <https://doi.org/10.1371/journal.pone.0238093>
- Hewson, A., Dent, S., & Sawers, A. (2020). Strength deficits in lower limb prosthesis users. *Prosthetics & Orthotics International*, 44(5), 323–340. <https://doi.org/10.1177/0309364620930176>
- John, S., Orlowski, K., Mrkor, K.-U., Edelmann-Nusser, J., & Witte, K. (2022). Differences in hip muscle strength and static balance in patients with transfemoral amputations classified at different k-levels: a preliminary cross-sectional study. *Canadian Prosthetics & Orthotics Journal*, 5(1). <https://doi.org/10.33137/cpoj.v5i1.37456>
- Kim, J., McDonald, C. L., Hafner, B. J., & Sawers, A. (2022). Fall-related events in people who are lower limb prosthesis users: The lived experience. *Disability and Rehabilitation*, 44(15), 3897–3908. <https://doi.org/10.1080/09638288.2021.1891467>
- Kolářová, B., Janura, M., Svoboda, Z., Kolář, P., Tečová, D., & Elfmark, M. (2021). Postural control strategies and balance-related factors in individuals with traumatic transtibial amputations. *Sensors*, 21(21), 7284. <https://doi.org/10.3390/s21217284>
- Lin, X., & Li, H. (2021). Obesity: Epidemiology, pathophysiology, and therapeutics. *Frontiers in Endocrinology*, 12. <https://doi.org/10.3389/fendo.2021.706978>

- Mollee, T. S., Dijkstra, P. U., Dekker, R., & Geertzen, J. H. B. (2021). The association between body mass index and skin problems in persons with a lower limb amputation: An observational study. *BMC Musculoskeletal Disorders*, 22(1), 769. <https://doi.org/10.1186/s12891-021-04646-2>
- Nishida, C. (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *The Lancet*, 363(9403), 157–163. [https://doi.org/10.1016/S0140-6736\(03\)15268-3](https://doi.org/10.1016/S0140-6736(03)15268-3)
- Ostolin, T. L. V. D. P., Gonze, B. de B., Jesus, M. O. de, Arantes, R. L., Sperandio, E. F., & Dourado, V. Z. (2020). Effects of obesity on postural balance and occurrence of falls in asymptomatic adults. *Fisioterapia Em Movimento*, 33. <https://doi.org/10.1590/1980-5918.033.ao50>
- Pagnotti, G. M., Haider, A., Yang, A., Cottell, K. E., Tuppo, C. M., Tong, K.-Y., Pryor, A. D., Rubin, C. T., & Chan, M. E. (2020). Postural stability in obese preoperative bariatric patients using static and dynamic evaluation. *Obesity Facts*, 13(5), 499–513. <https://doi.org/10.1159/000509163>
- Rachmat, N., Syaifudin, M., & Hanifah, H. (2017). Indeks massa tubuh dengan keseimbangan statis pengguna transtibial prosthesis. *Jurnal Kesehatan*, 8(3), 425. <https://doi.org/10.26630/jk.v8i3.630>
- Rusaw, D. F., Alinder, R., Edholm, S., Hallstedt, K. L. L., Runesson, J., & Barnett, C. T. (2021). Development of a theoretical model for upright postural control in lower limb prosthesis users. *Scientific Reports*, 11(1), 8263. <https://doi.org/10.1038/s41598-021-87657-2>
- Sartika, M., Sartika, A., Tahanora, R. T., Nurpratiwi, Y., & Rahayu, P. (2025). Screening kejadian vertigopada lansia di Sentra Terpadu Pangudi Luhur Kota Bekasi. *Connection: Jurnal Pengabdian Kepada Masyarakat*, 5(2), 248–257. <https://doi.org/10.32505/connection.v5i2.12154>
- Sawers, A., & Fatone, S. (2022). Normalization alters the interpretation of hip strength in established unilateral lower limb prosthesis users. *Clinical Biomechanics*, 97, 105702. <https://doi.org/10.1016/j.clinbiomech.2022.105702>
- Shafiq, U. R., Ahmed, A., Kamran, M., Saqulain, G., & Idrees, N. (2023). Association of quality of life with body mass index in patients using trans femoral prosthesis after amputation specialist orthotics paraplegic center Peshawar Pakistan Specialist Orthotics Prosthetist Chal Foundation Bacha Khan Medical complex. *Journal Riphah College of Rehabilitation Science*, 11, 40–46. <https://doi.org/10.53389/JRCRS.2023110109>
- World Health Organization. (2021). *Obesity and overweight*. Retrieved October 1, 2026, from <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>