

Restoring Culturally Essential Floor-Sitting in Transfemoral Prosthesis Users: A Six-Week Pilot Randomized Within-Subject Trial

Natthawan Sutthison, M.Sc.¹, Nang Myat Myat Moe, M.Sc.¹, Yasmin Nutchamlong, B.P.O.¹, Marisa Amattayakul, B.P.O.¹, Mathurin Rairat, B.P.O.¹, Woratee Dacharux, M.D.², Gary Guerra, Ph.D.³, Kazuhiko Sasaki, Ph.D.^{1,*}

¹Sirindhorn School of Prosthetics and Orthotics, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand, ²Department of Anatomy, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand, ³Department of Exercise and Sport Science, St. Mary's University, San Antonio, Texas, USA.



Restoring Culturally Essential Floor-Sitting with the Asian Transfemoral Socket

(A six-week pilot randomized within-subject trial)

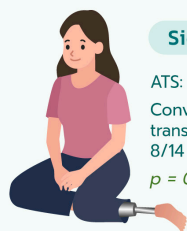
Concept Asian Transfemoral Socket: ATS

For people with transfemoral amputation in Asia, this low-profile, femoral-adducted socket restores floor-sitting through geometry alone, without compromising walking function.

Key Points

- Socket geometry alone restored floor-sitting
- Mobility was preserved; comfort improved

Main Results: Floor-sitting attainment (%)



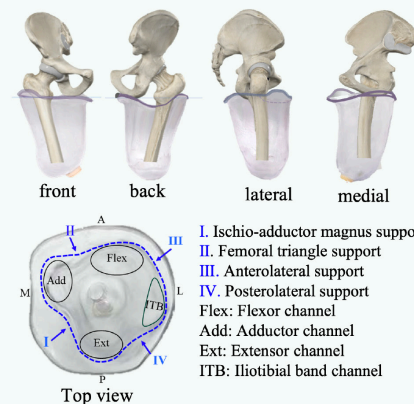
Side-sitting

ATS: 14/14 (100%)
Conventional transfemoral socket: 8/14 (57.1%)
 $p = 0.031$



Cross-legged sitting

ATS: 12/14 (85.7%)
Conventional transfemoral socket: 0/14 (0%)
 $p < 0.001$



Conclusion Over six weeks, the ATS improved floor-sitting, comfort, and prosthesis-related quality of life without mobility loss: a culturally responsive, maintainable option for resource-limited Asia.

SCAN FOR FULL TEXT



SMJ

SIRIRAJ
MEDICAL
JOURNAL

Sutthison, et al. *Siriraj Med J* 2026;78(10):793-804.

©Siriraj Medical Journal. All rights reserved. Graphical abstract by K Suriyapornpun



All material is licensed under terms of the Creative Commons Attribution 4.0 International (CC-BY-NC-ND 4.0) license unless otherwise stated.

*Corresponding author: Kazuhiko Sasaki

E-mail: kazuhiko.sas@mahidol.ac.th

Received 24 July 2026 Revised 3 September 2026 Accepted 4 September 2026

ORCID ID: <http://orcid.org/0000-0002-1778-6308>

<https://doi.org/10.33192/smj.v78i10.283845>

ABSTRACT

Objective: Floor-sitting, including cross-legged and side-sitting, is culturally essential in many Asian societies but is often prevented by conventional transfemoral sockets. The Asian Transfemoral Socket (ATS) is a low-profile, femoral-adducted design that aims to restore floor-sitting through socket geometry rather than costly add-on components.

Materials and Methods: In a pilot randomized within-subject trial, 14 community walkers with unilateral transfemoral amputation were assessed with the ATS after six weeks of use and with their own socket, in randomized order. The primary outcome was floor-sitting attainment (cross-legged and side-sitting); secondary outcomes were socket comfort (SCS), prosthesis-related quality of life (PEQ), walking capacity (6MWT), dynamic balance (4SST), and daily step count. Outcomes were analyzed using Wilcoxon signed-rank and McNemar tests, with rank-biserial correlations as effect sizes.

Results: Cross-legged was attained by 12 participants with the ATS ($p < 0.001$) and side-sitting by 6 additional participants ($p = 0.031$). The ATS showed large effect sizes on comfort and quality of life, significant on two of four SCS ratings and two of three PEQ scales, whereas walking, balance, and activity did not differ (6MWT $r = 0.09$; 4SST $r = 0.29$; steps $r = -0.05$).

Conclusion: The ATS was associated with better floor-sitting and patient-reported outcomes. No statistically supported mobility difference was detected (paired median differences: 6MWT +0.4 m [95% CI -3.5 to 11.3], 4SST -0.21 s [-0.44 to 0.21], steps/day -23 [-449 to 521]); clinically important harm cannot be excluded. Cost, fabrication time, training, maintenance, and service delivery were not evaluated; findings are limited to this Thai center.

Keywords: Transfemoral prosthesis; socket design; floor-sitting; quality of life; resource-limited setting (Siriraj Med J 2026;78(10):793-804)

INTRODUCTION

Floor-sitting is routine and culturally embedded in many Asian societies.¹ Cross-legged sitting and side-sitting are used during meals, family gatherings, social interaction, and religious ceremonies, and may recur repeatedly throughout daily life.²⁻⁴ For transfemoral prosthesis users, inability to floor-sit is linked to body function, activity, and participation under the International Classification of Functioning, Disability and Health (ICF) framework.⁵⁻⁷

Conventional transfemoral sockets such as quadrilateral and ischial-containment designs were primarily developed to provide stability, load transfer, and control during standing and walking.⁸⁻¹⁰ However, they restrict the combined hip flexion, abduction, and rotation required for floor-sitting because of their high proximal trim lines and pelvic enclosure.^{11,12} Mechanical rotation adapters integrated into the prosthesis between the transfemoral socket and knee may facilitate controlled axial rotation of the prosthetic limb and increase sitting mobility; however, they add cost and weight, increase the mechanical complexity of the prosthetic system and the need for technical adjustment, and impose a maintenance burden, which limits feasibility in resource-limited Asian settings.^{6,13,14} Low-profile socket designs, such as the Marlo Anatomical Socket (MAS) or Sub-ischial socket, may improve hip motion, comfort, or function.

However, MAS depends principally on specialized casting, rectification, and fitting expertise, and its implementation may require specialized clinician training. Sub-ischial sockets typically require silicone gel liners, vacuum unit systems, and greater maintenance.^{8,15-17}

We designed the Asian Transfemoral Socket (ATS), a low-profile, femoral-adducted transfemoral socket for Asian transfemoral prosthesis users living in floor-sitting cultures. The ATS aims to restore culturally essential floor-sitting through socket geometry and anatomical load distribution rather than costly add-on components. The ATS has lowered proximal trim lines, a reduced ischial containment region, a subtrochanteric lateral contour, and approximately 6 degrees of socket adduction (Fig 1).¹⁸ In this way it permits greater hip motion during floor-sitting while maintaining sufficient support for walking. This pilot randomized within-subject study analyzed effects of ATS compared with the own socket of the participant after six weeks of daily use. Study outcomes were floor-sitting attainment, socket comfort, prosthesis-related quality of life, walking capacity, dynamic balance, and daily step count.

MATERIALS AND METHODS

Asian Transfemoral Socket

The ATS uses lowered proximal trim lines, with the lateral wall reduced to a level below the greater trochanter,

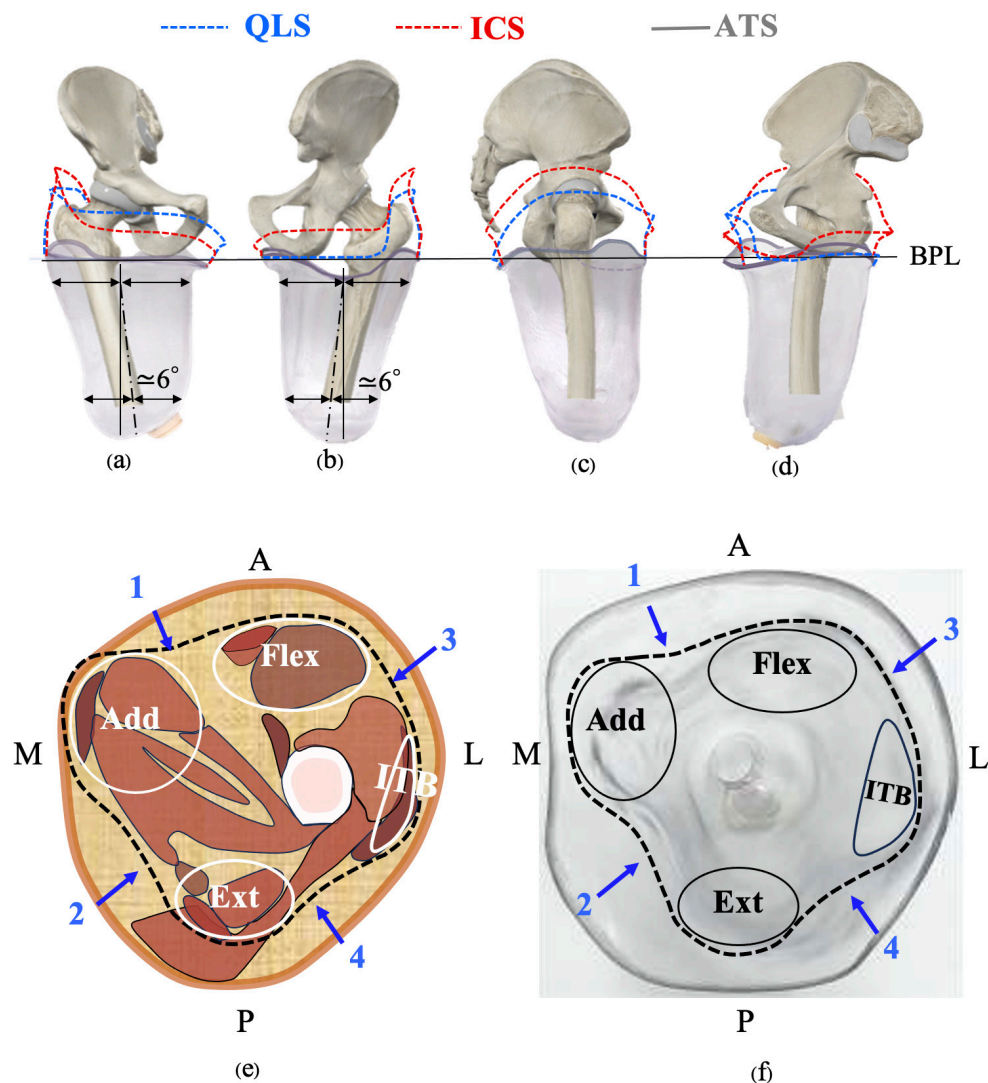


Fig 1. Asian Transfemoral Socket (ATS): (a) anterior, (b) posterior, (c) lateral, and (d) medial views; (e) cross-sectional view of the ATS and residual limb; and (f) cross-sectional view showing biomechanical forces. In (a–d), the blue dashed line represents the quadrilateral socket (QLS), and the red dashed line represents the ischial containment socket (ICS). In (a,b), the black dash-dot line indicates approximately 6° of socket adduction. In (e,f), the black dashed line indicates the contour 25 mm distal to the Below Pelvic Level (BPL). 1, femoral triangle support; 2, ischio-adductor magnus support; 3, anterolateral support; 4, posterolateral support.

Abbreviations: ATS, Asian Transfemoral Socket; QLS, quadrilateral socket; ICS, ischial containment socket; Flex, flexor channel; Add, adductor channel; Ext, extensor channel; ITB, iliotibial band channel.

aiming to facilitate hip motion during floor-sitting while reducing mechanical interference with the floor surface and peri-pelvic soft tissues. Rather than enclosing the ischium within a high proximal wall, it distributes load through anatomical support regions of the pelvis and thigh and through an inclined ischial support that contains the ischial ramus without raising a proximal wall, reducing perineal compression during the hip flexion, abduction, and external rotation of cross-legged sitting. In the frontal plane, the socket was aligned at approximately 6 degrees of adduction, based on Köhler et al.,¹⁸ to support frontal-plane stability during gait. The ATS thus integrates the hip mobility required for floor-sitting with the stability required for standing and walking (Fig 1).

Study

The study was conducted at the Sirindhorn School of Prosthetics and Orthotics, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand, and was approved by the Siriraj Institutional Review Board (COA no. Si 703/2022; 4 October 2022). Written informed consent was obtained from all participants. Enrollment occurred from 6 October 2022 to 24 March 2024. The trial was retrospectively registered with the Thai Clinical Trials Registry (TCTR20260619005; <https://www.thaiclinicaltrials.org/show/TCTR20260619005>) because clinical-trial registration was temporarily suspended when enrollment began. No protocol deviations relevant to this trial occurred.

Participants

Individuals with a unilateral transfemoral amputation were recruited via a poster at the SSPO clinic. Interested individuals received verbal and written study information from co-investigators (Y.N. and M.R.) and provided written informed consent before enrollment. Inclusion criteria were adult (≥ 18 years) unilateral transfemoral prosthesis user with a well-fitted current prosthesis; at least six months of prosthetic use; Medicare Functional Classification Level K2 or higher, able to walk independently on level ground without a walking aid; a residual limb more than 15 cm; body mass index 17-25 kg/m²; and ability to communicate in Thai. Exclusion criteria were comorbidities precluding the physical outcome tests; bilateral major lower-limb amputations; surgery on the non-amputated side; limited hip range of motion on both sides; a manual-muscle-test grade below four in either lower limb; residual-limb edema, wounds, or allergy to socket plastics; and difficulties in comprehension or communication. Because the protocol required exclusive ATS use during its six-week period, participants were required to refrain from using their own socket to avoid mixed-device exposure during assessment. The own socket of the participant was held in safekeeping and returned on request, on withdrawal, or if the ATS became unsuitable. Participants who wished to continue using the ATS after the study could keep it free of charge; this IRB-approved option was disclosed during informed consent and was not conditional on study completion. The authors had no financial or intellectual-property interest in the ATS.

Study design

In this single-center, two-period, two-sequence randomized crossover trial, we compared the ATS with the own socket of the participant. After eligibility was confirmed, participants were assigned 1:1 to the own-socket-first or ATS-first sequence using a pre-generated block-randomized sequence with a fixed block size of 2. The first author enrolled participants; sequence assignment was made after written informed consent according to chronological enrollment order. No separate allocation-concealment mechanism was used. In the own-socket-first sequence, outcomes were assessed at baseline from the established everyday use of each participant, after which participants used the ATS for a six-week daily-use period and were reassessed. In the ATS-first sequence, no outcome assessment was performed at baseline; participants used the ATS for six weeks and were assessed, then resumed their own socket use and were reassessed after a further six weeks. The ATS condition, therefore,

always comprised a six-week ATS use period, whereas the own-socket condition reflected the normal everyday use of each participant. A common pre-randomization outcome assessment was not included in the original design, and no formal washout was used. Because own-socket assessment timing differed by sequence, period and sequence effects were examined in exploratory crossover models; residual learning, accommodation, or carryover cannot be excluded. A six-week ATS use period was chosen because the Prosthesis Evaluation Questionnaire (PEQ) requires at least four weeks of use. Two weeks after the start of ATS use, socket fit was reassessed and safety checks were performed. If no fitting problems were identified, participants continued using the ATS for the remaining four weeks, completing a total of six weeks of ATS use before assessment.

Socket casting, fabrication, and alignment standardization

All sockets were single-wall suction sockets fabricated without gel liners or vacuum assistance, using a standardized casting and rectification protocol targeting approximately 6 degrees of socket adduction.^{15,19} Two prosthetists fabrication and fitting the ATS sockets using an identical protocol. To avoid component-related confounding, the own prosthetic components of each participant were transferred unchanged to the ATS, and alignment was standardized so that the ATS load line and the static socket-knee-foot relationship matched those of the existing prosthesis of the participant. Because the ATS was readily distinguishable from the own socket of each participant, blinding was not feasible. Therefore, fabrication and fitting (K.S. and N.M.), outcome assessment (Y.N., M.A., and M.R.), and data processing (N.S.) were performed by different persons. Before analysis, socket-condition labels were replaced with neutral alphanumeric codes by co-investigators (Y.N. and N.M.).

Outcome measurements

Wear compliance and fitting-related complications were monitored by telephone at Week 1. Daily ambulatory activity was recorded continuously by a small pedometer fixed in a protective capsule on the prosthetic shank. The pedometer could neither be read nor adjusted by the participant. Outcomes are reported throughout in the following order, beginning with the most important: floor-sitting attainment (primary), socket comfort (Socket Comfort Score, SCS), prosthesis-related quality of life (Prosthesis Evaluation Questionnaire, PEQ), walking capacity (Six-Minute Walk Test, 6MWT), dynamic balance (Four-Square Step Test, 4SST), and daily step count. Each outcome, with its measurement properties, is

described below. As an exploratory acceptability outcome, we asked the participant at the end of the ATS period whether they wished to keep the ATS or resume using their own socket.

Floor-sitting attainment was the primary outcome domain, assessed separately for cross-legged and side-sitting; neither posture was designated as a separate co-primary endpoint. The same prespecified 10-s criteria were applied by one unblinded assessor. Any attempt that did not satisfy all stated attainment criteria was scored as not attained. Because this test was developed for the present study, no published reliability or validity estimates are available; no repeated-rating reliability estimate or video-adjudication result is available. This is consistent with the reported lack of psychometrically established outcome measures for culturally important floor-sitting activities in people with lower-limb absence.²⁰

The SCS measures self-reported socket comfort on an 11-point numerical rating scale (0-10, higher = better); in an expanded administration, participants rated current comfort plus their best, worst, and average comfort over the preceding week. It has acceptable test-retest reliability and construct validity in lower-limb prosthesis users.²¹

The PEQ measures prosthesis-related quality of life; the Utility, Residual Limb Health, and Ambulation scales (0-100, higher = better) were administered at six weeks. These scales have acceptable test-retest reliability and construct validity in this population.²²

The 6MWT measures submaximal walking capacity as the distance walked in six minutes.²³ It has established validity and test-retest reliability in people with lower-limb amputation.^{24,25}

The 4SST measures dynamic balance as the time taken to step over four quadrants in both directions; it was performed twice and the faster trial was retained. It has high test-retest and inter-rater reliability,^{26,27} and discriminates multiple fallers after amputation.²⁸

Daily step count measures habitual ambulatory activity and was recorded continuously using a tri-axial accelerometer pedometer (H-235 Daily Partner, Dretec, Japan) mounted on the prosthetic shank. The manufacturer specifies $\pm 3\%$ step-count accuracy under vibration testing; prosthesis-mounted accelerometer monitors have demonstrated criterion validity, although accuracy may decrease at slow walking speeds.²⁹

Floor-sitting evaluation

Floor-sitting was assessed in two postures common in Thai daily life. Cross-legged sitting evaluated the combined external rotation, flexion, and abduction of

the prosthetic-side hip; attainment required the sound and prosthetic lower legs to cross in front of the pelvis with the foot of each leg contacting the opposite lower leg (Fig 2a,b; a failed attempt is shown in Fig 2e,f). The sound limb was positioned inward first, and the prosthetic foot was then placed in front of the sound lower leg, so that any hip-motion restriction on the prosthetic side did not affect the movement of the sound side. Side-sitting evaluated the combined internal rotation, flexion, and abduction of the prosthetic-side hip; attainment required the sound foot and the prosthesis to be in contact after the participant had assumed the posture (Fig 2c,d; a failed attempt is shown in Fig 2g,h). Participants were permitted to use their hands while moving into each position; once seated, they held both hands at chest level and maintained the posture for 10 s without arm support. Satisfying the posture condition and holding it for 10 s without arm support was scored 1 (attained); requiring arm support was scored 0 (not attained).

Sample size

As an exploratory pilot, sample size was selected pragmatically. Whitehead et al.³⁰ informed pilot planning but did not provide power justification for the paired binary primary outcome; no formal progression criteria were prespecified.

Analysis

Floor-sitting attainment, the primary outcome domain, was summarized as the number and percentage of participants attaining each posture in each socket condition, with Clopper-Pearson exact binomial 95% confidence intervals, and between-socket paired comparisons were performed using the exact two-sided McNemar test. The secondary outcomes were then analyzed in the same fixed order: socket comfort, prosthesis-related quality of life, walking capacity, dynamic balance, and daily step count. Within-subject comparisons between the ATS and the own socket of the participant were summarized as medians with interquartile ranges (IQR) and tested using the Wilcoxon signed-rank statistic with exact sign-permutation *p* values; zero differences were excluded and ties received midranks. Effect sizes were calculated as matched-pairs rank-biserial correlations (*r*) from the same signed-rank statistics, with positive *r* values indicating ATS superiority. For the 4SST, the difference sign was reversed so that faster times yielded positive *r* values. The 95% confidence intervals were estimated by paired bootstrap resampling of participants using 10,000 resamples and the bias-corrected and accelerated (BCa) method. Effect-sizes were interpreted as negligible

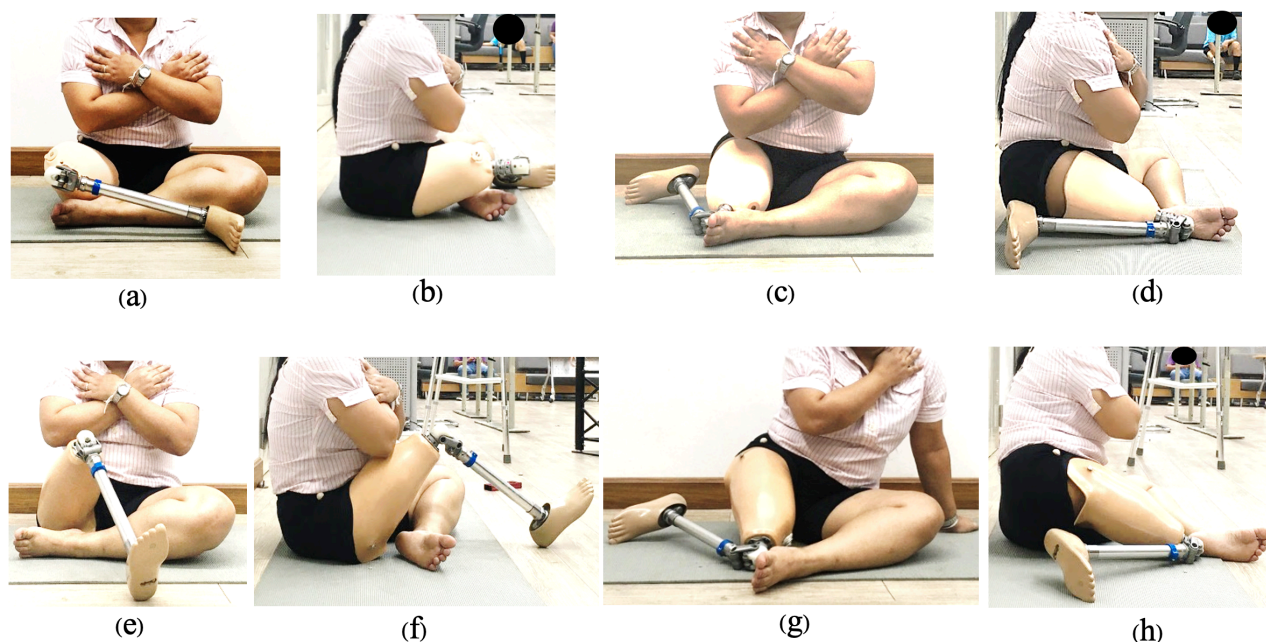


Fig 2. Floor-sitting task outcomes. Panels (a,b) and (c,d) show attained cross-legged sitting and side-sitting; panels (e,f) and (g,h) show failed attempts. Within each pair, the first panel shows the frontal view, and the second shows the lateral view. A posture was scored as attained when held for 10 s without arm support; full attainment criteria are given in the Methods section.

(< 0.10), small (< 0.30), medium (< 0.50), and large (≥ 0.50). No multiplicity adjustment was prespecified; secondary *p* values were treated as descriptive and interval estimates were emphasized. All analyses were performed in R 4.6.1 using the stats and boot (1.3-32) packages, with figures produced in ggplot2. Exploratory crossover models included treatment, period, and sequence with participant-clustered standard errors (Supplementary Table S1). Additional crossover analyses were performed in Python 3.13.5 using statsmodels 0.14.6.

RESULTS

Seventeen individuals with a unilateral transfemoral amputation were assessed for eligibility. Two participants were excluded before randomization: one had an extremely short residual limb that did not meet the length criterion, and one used an exoskeletal prosthesis that precluded safe standardization of the distal components. The remaining 15 participants were randomized: seven to the own-socket-first sequence and eight to the ATS-first sequence. One participant in the ATS-first sequence developed transient pruritus and erythema after contact with suction-valve materials and talcum powder, together with suspension problems, during the first two weeks after randomization and discontinued ATS use. Symptoms resolved within a few hours without medication or hospitalization; severity was not formally graded. All 15 randomized participants were included in safety reporting. The remaining 14 participants (13 men, 1 woman) completed both conditions

and contributed paired efficacy data (complete-case estimand), leaving seven completers in each sequence (Table 1 and Fig 3). Of the 14 completers, six habitually used a quadrilateral socket and eight an ischial containment socket, and all used suction suspension (Supplementary Table S2). No serious adverse event occurred. In a worst-case primary-outcome sensitivity analysis coding the missing participant as ATS failure and own-socket success, cross-legged attainment remained statistically supported (McNemar $p = .003$), whereas side-sitting did not ($p = .125$). Floor-sitting attainment, the median values, effect sizes, and confidence intervals for the continuous and ordinal outcomes are presented in Table 2. Self-reported comfort and quality-of-life estimates generally favored the ATS, whereas no statistically supported difference was detected in objective walking or activity measures.

Floor-sitting attainment

Cross-legged sitting and side-sitting were significantly more often attained when using the ATS compared to when using their own socket (Table 2).

Socket comfort and prosthesis-related quality of life

SCS and PEQ findings are exploratory (Table 2). Nominal *p* values were .049 for SCS Worst, .035 for SCS Today, .048 for PEQ Residual Limb Health, and .003 for PEQ Ambulation; other SCS/PEQ comparisons had $p = .057-.072$. After the final outcome assessment, before data analysis or disclosure of results, participants were

TABLE 1. Baseline characteristics of all randomized participants by sequence (N = 15).

Characteristic	Own-socket-first (n=7)	ATS-first (n=8)	Total (N=15)
Continuous variables, median (IQR)			
Age, years	44.0 (43.0-48.0)	53.0 (44.8-62.8)	49.0 (43.0-58.5)
Body mass, kg	59.5 (56.5-65.5)	62.5 (58.8-69.8)	62.0 (56.5-68.5)
BMI, kg/m ²	22.4 (20.6-24.2)	23.1 (20.3-24.5)	23.1 (20.1-24.5)
Residual limb length, cm	24.5 (23.0-27.8)	20.5 (18.5-21.6)	21.8 (19.5-24.3)
Femur length, cm	21.5 (20.3-23.5)	18.3 (16.9-20.3)	20.0 (17.0-21.3)
Time since amputation, years	22.0 (6.5-27.5)	27.0 (12.0-29.3)	26.0 (10.0-28.5)
Categorical variables, n (%)			
Sex			
Male	6 (85.7)	8 (100.0)	14 (93.3)
Female	1 (14.3)	0 (0.0)	1 (6.7)
Amputation side			
Right	4 (57.1)	4 (50.0)	8 (53.3)
Left	3 (42.9)	4 (50.0)	7 (46.7)
Cause of amputation			
Trauma	4 (57.1)	6 (75.0)	10 (66.7)
Cancer	1 (14.3)	2 (25.0)	3 (20.0)
Infection	2 (28.6)	0 (0.0)	2 (13.3)
Medicare Functional Classification Level			
K2	2 (28.6)	0 (0.0)	2 (13.3)
K3	5 (71.4)	8 (100.0)	13 (86.7)

Note. Values are median (IQR) or n (%). The participant who discontinued ATS after randomization is included in the ATS-first baseline column. Residual limb length is measured from the ischial tuberosity to the distal end of the residual limb. BMI, body mass index; K2/K3, Medicare Functional Classification Level.

asked whether they wished to keep the ATS or resume their own socket. Neither choice involved study-related cost; 12 of 14 (85.7%) chose the ATS.

Functional capacity and daily activity

No statistically supported difference was detected for 6MWT, 4SST, or step count (Table 2). In exploratory crossover models, the ATS treatment estimate was +1.71 SCS points for Worst (95% CI 0.52 to 2.91) and +9.89 PEQ Utility points (2.76 to 17.02). Period effects were also present for these outcomes, whereas sequence terms

were not statistically supported (Supplementary Table S1). These model-based estimates are exploratory.

DISCUSSION

This trial tested whether a low-profile, femoral-adducted transfemoral socket can restore culturally important floor-sitting without sacrificing walking function. Over six weeks of real-life use, the ATS tended to improve floor-sitting attainment, socket comfort, and prosthesis-related quality of life, while functional capacity and habitual activity remained unchanged, suggesting

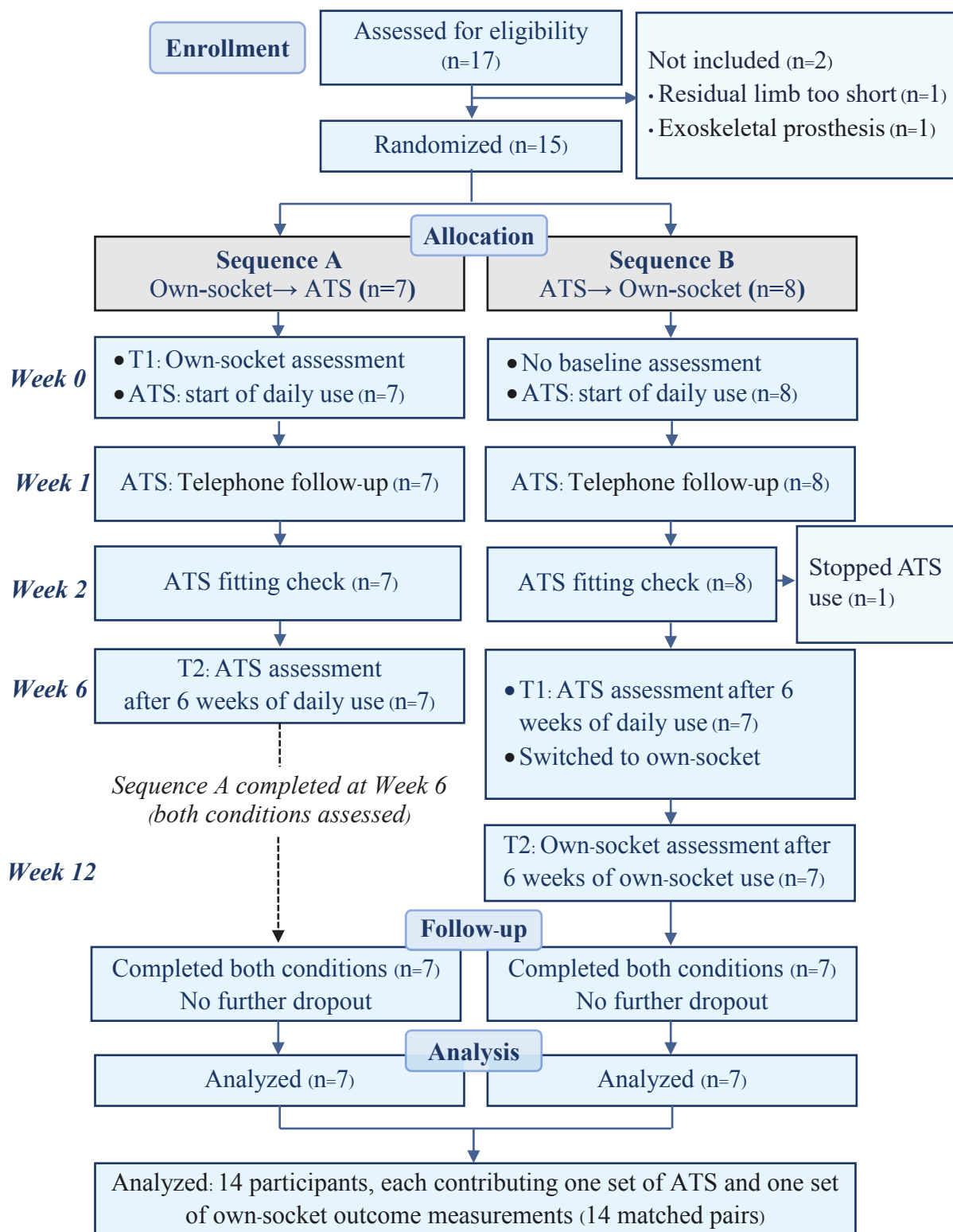


Fig 3. CONSORT flow diagram of the randomized within-subject trial. T1: first outcome measurements; T2: second outcome measurements
Abbreviation: ATS: Asian Transfemoral Socket

TABLE 2. Within-subject comparison of the ATS and the own socket of the participant across postural attainment, socket comfort, self-reported outcomes, functional capacity, and daily activity ($N = 14$).

Posture	ATS	Own socket	ATS % [95% CI]	Own socket % [95% CI]	<i>p</i>
	<i>n/N</i>	<i>n/N</i>			
Cross-legged sitting	12/14	0/14	85.7 [57.2, 98.2]	0.0 [0.0, 23.2]	< .001
Side-sitting	14/14	8/14	100.0 [76.8, 100.0]	57.1 [28.9, 82.3]	.031
Outcome	ATS Median (IQR)	Own socket Median (IQR)	Effect size <i>r</i> [95% CI]	<i>p</i>	
Socket comfort					
SCS: Best	9.0 (8.2-10.0)	9.0 (8.0-9.0)	0.67 [0.00, 1.00]	.072	
SCS: Worst	8.5 (6.2-9.0)	6.5 (5.0-7.8)	0.63 [0.02, 0.92]	.049	
SCS: Average	9.0 (8.1-10.0)	8.0 (7.0-9.0)	0.60 [-0.05, 0.92]	.057	
SCS: Today	9.0 (8.2-10.0)	8.5 (8.0-9.0)	0.80 [-0.14, 1.00]	.035	
Quality of life (Self-reported)					
PEQ: UT	87.8 (82.6-89.7)	80.2 (72.1-85.8)	0.55 [-0.10, 0.90]	.070	
PEQ: RLH	84.6 (69.6-90.5)	77.3 (71.0-82.2)	0.60 [-0.09, 0.98]	.048	
PEQ: AB	94.7 (87.9-96.7)	87.1 (83.2-91.8)	0.85 [0.26, 1.00]	.003	
Functional capacity and daily activity					
6MWT	350.6 (314.6-384.6)	353.9 (318.9-379.0)	0.09 [-0.52, 0.66]	.808	
4SST	10.4 (9.2-11.4)	10.2 (9.6-11.7)	0.29 [-0.35, 0.77]	.365	
Step count	2690 (1074-4720)	1993 (1027-5505)	-0.05 [-0.62, 0.54]	.903	

Note. Floor-sitting values are n/N (%) with Clopper-Pearson 95% CIs and exact McNemar p values. Continuous/ordinal values are median (IQR); r is matched-pairs rank-biserial correlation with BCa 95% CI. Wilcoxon p values are exact sign-permutation values. Non-zero pairs for SCS Best, Worst, Average, and Today were 10, 13, 13, and 9; all PEQ scales, 6MWT, 4SST, and step count had 14. Secondary p values are descriptive because multiplicity was not adjusted. For 4SST, positive r indicates faster ATS performance.

Abbreviation: ATS, Asian Transfemoral Socket; SCS, Socket Comfort Score; PEQ, Prosthesis Evaluation Questionnaire; UT, Utility; RLH, Residual-Limb Health; AB, Ambulation; 6MWT, Six-Minute Walk Test; 4SST, Four-Square Step Test.

that the benefit for floor-sitting was not gained at the cost of walking.

Floor-sitting, comfort, and quality of life

Floor-sitting showed the largest and most clinically relevant differences. Cross-legged sitting was not achieved by any participant in their own socket, whereas 12 of 14 participants achieved it with the ATS. This result is consistent with earlier reports that cross-legged sitting is extremely difficult for transfemoral prosthesis users whereas it is a valued determinant of quality of life.^{6,7} The fact that side-sitting was already attainable for 8

participants yet improved further to 14 with the ATS fits the interpretation that side-sitting can be partly achieved through compensatory pelvic tilt. Cross-legged sitting depends more directly on hip external rotation which a conventional high lateral wall and ischial brim obstruct. SCS estimates generally favored the ATS but were imprecise: $r = 0.67$ [0.00, 1.00] for Best, 0.63 [0.02, 0.92] for Worst, 0.60 [-0.05, 0.92] for Average, and 0.80 [-0.14, 1.00] for Today (BCa 95% CIs). PEQ Ambulation showed the clearest six-week estimate ($r = 0.85$ [0.26, 1.00]); these unblinded subjective outcomes remain exploratory.

Functional capacity and daily activity

A potential concern with lowering the proximal trim lines is reduced mediolateral control during gait. No statistically supported between-socket difference was detected for 6MWT, 4SST, or step count. Median paired differences (ATS-own socket) were +0.4 m (95% CI -3.5 to 11.3), -0.21 s (-0.44 to 0.21), and -23 steps/day (-449 to 521), respectively. Because this pilot was not a non-inferiority study and the intervals remain wide, clinically important mobility changes cannot be excluded; preserved mediolateral control was not established. Prior biomechanical evidence suggests that removing ischial containment may not substantially affect frontal-plane hip moments, lateral trunk lean, step width, or walking speed.^{16,17} Frontal-plane stability may also depend on socket adduction alignment. Köhler et al. reported that adduction of approximately 6 degrees reduced compensatory lateral trunk lean during prosthetic-side stance.¹⁸ Because the ATS combines this adduction with distal femoral centralization,¹⁹ proximal support may be redistributed through alignment and anatomical load-sharing rather than being simply reduced. Increased rotational freedom may be a further mechanism but, with transverse-plane motion unmeasured, remains hypothetical. The divergence between subjective and objective outcomes is not necessarily contradictory: the objective tests captured short, supervised capacity, where a well-aligned conventional socket and the ATS may perform similarly, whereas the self-reported measures reflected a week of habitual use including floor-sitting. The fact that worst- and average-comfort ratings improved over the week, not only on the day-of rating, also argues against a purely novelty effect.

Cultural sustainability and rehabilitation relevance

Framed within the ICF, the results trace a coherent path from body function to participation. By releasing the combined hip motion that floor-sitting demands (body function), the ATS restored cross-legged and side-sitting (activity), the postures through which meals, social gatherings, and religious ceremonies are conducted in many Asian communities (participation).¹ This path reframes socket design as a participation-oriented, culturally responsive rehabilitation goal, consistent with inclusive, equitable rehabilitation for under-served populations.^{13,14} Importantly, the ATS achieves its intended function through socket geometry and alignment rather than additional components such as rotation adapters, vacuum suspension systems, or specialized prosthetic liners, which may reduce component-related costs and maintenance requirements in resource-limited settings. However, formal cost data were not collected in this study.

Limitations

Several limitations should be considered. First, this was a small, single-center study of 14 predominantly male participants, which limits statistical power and generalizability. In addition, participants had medium to long residual limbs, longer than 15 cm, and therefore the findings may not be directly generalizable to short or very short residual limbs. The within-subject design reduced between-participant variability, but a fully placebo-controlled crossover trial was not feasible because prosthetic sockets must be individually fabricated, aligned, and accommodated, and the ATS was visibly different from the own socket of the participants. Consequently, blinding was not possible, and self-reported comfort, PEQ scores, and device preference may have been influenced by expectation, novelty, or the option to keep the ATS after the study. Second, the six-week follow-up was sufficient to assess short-term accommodation and daily use but not long-term durability, maintenance burden, residual-limb volume change, skin tolerance, or sustained satisfaction. Third, floor-sitting was evaluated as binary attainment rather than by three-dimensional kinematics or interface-pressure measurement; therefore, the proposed mechanisms linking lowered trim lines to improved hip motion remain inferential. In addition, the floor-sitting attainment test was developed for this study, so its reliability and validity have not been formally established, although a priori criteria and a single rater were used to limit measurement error. Larger, multicenter, longer-term studies with biomechanical assessment are needed to confirm or refute effectiveness, clarify mechanisms, and evaluate clinical sustainability in routine practice.

CONCLUSION

This six-week randomized within-subject trial suggests that the Asian Transfemoral Socket improves culturally important floor-sitting, socket comfort, and prosthesis-related quality of life without any evident short-term reduction in walking capacity, balance, or daily activity.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

ACKNOWLEDGEMENTS

We thank the participants for their invaluable contribution to this study. We also extend our gratitude to the Sirindhorn School of Prosthetics and Orthotics, Faculty of Medicine, Siriraj Hospital, Mahidol University, for their institutional support. We further acknowledge

the postgraduate and research teams for their assistance with the project. This research was supported by the Siriraj Research Development Fund, managed by Routine to Research (R2R), Faculty of Medicine Siriraj Hospital, Mahidol University, grant number (IO) R016635042.

DECLARATIONS

Grants and Funding Information

This research was supported by the Siriraj Research Development Fund (managed by Routine to Research, R2R), Faculty of Medicine Siriraj Hospital, Mahidol University (Grant No. R016635042).

Conflict of Interest

No potential conflict of interest was reported by the authors.

Registration Number of Clinical Trial

The Thai Clinical Trials Registry (TCTR20260619005).

Author Contributions

Conceptualization and methodology, N.S., K.S., G.G., W.D. ; Investigation, N.M., Y.N., M.A., M.R., K.S. ; Formal analysis, N.S., G.G. ; Visualization and writing – original draft, N.S. ; Writing – review and editing, N.S., K.S., G.G. ; Funding acquisition, N.S., K.S. ; Supervision, K.S., G.G., W.D. All authors have read and agreed to the final version of the manuscript.

Use of Artificial Intelligence

The authors declare no use of artificial intelligence.

Institutional Review Board Statement

The study was conducted at the Sirindhorn School of Prosthetics and Orthotics (SSPO), Faculty of Medicine Siriraj Hospital, Mahidol University, approved by the Siriraj Institutional Review Board (COA no. Si 703/2022), carried out in accordance with the Declaration of Helsinki, with written informed consent from all participants.

REFERENCES

- Hewes GW. World distribution of certain postural habits. *Am Anthropol*. 1955;57(2):231–44.
- Kapoor A, Mishra SK, Dewangan SK, Mody BS. Range of movements of lower limb joints in cross-legged sitting posture. *J Arthroplasty*. 2008;23(3):451–3.
- Zhou H, Liu A, Wang D, Zeng X, Wei S, Wang C. Kinematics of lower limbs of healthy Chinese people sitting cross-legged. *Prosthet Orthot Int*. 2013;37(5):369–74.
- Ganokroj P, Chaowalitwong J, Kerdsonnuek P, et al. Three-dimensional motion analysis of ten common Asian sitting positions in daily living and factors affecting range of hip motions. *BMC Musculoskelet Disord*. 2021;22:618.
- World Health Organization. International Classification of Functioning, Disability and Health: ICF. Geneva: World Health Organization; 2001.
- Cavuto ML, Chun M, Kelsall N, et al. Design of mechanism and preliminary field validation of low-cost transfemoral rotator for use in the developing world. In: *Proceedings of the ASME 2016 International Design Engineering Technical Conferences*; 2016 Aug 21–24; Charlotte, NC, USA. V05AT07A035.
- Horgan O, MacLachlan M. Psychosocial adjustment to lower-limb amputation: a review. *Disabil Rehabil*. 2004;26(14–15):837–50.
- Brodie M, Murray L, McGarry A. Transfemoral prosthetic socket designs: A review of the literature. *J Prosthet Orthot*. 2022;34(2):e73–e92.
- Radcliffe CW. Functional considerations in the fitting of above-knee prostheses. Berkeley (CA): Biomechanics Laboratory, University of California; 1955.
- Sabolich J. Contoured adducted trochanteric-controlled alignment method (CAT-CAM): Introduction and basic principles. *Clin Prosthet Orthot*. 1985;9(4):15–26.
- Hagberg K, Häggström E, Uden M, Brånemark R. Socket versus bone-anchored transfemoral prostheses: Hip range of motion and sitting comfort. *Prosthet Orthot Int*. 2005;29(2):153–63.
- Klotz R, Colobert B, Botino M, Permentiers I. Influence of different types of sockets on the range of motion of the hip joint by the transfemoral amputee. *Ann Phys Rehabil Med*. 2011;54(7):399–410.
- Harkins CS, McGarry A, Buis A. Provision of prosthetic and orthotic services in low-income countries: A review of the literature. *Prosthet Orthot Int*. 2013;37(5):353–61.
- Craig J. Prosthetic feet for low-income countries. *J Prosthet Orthot*. 2005;17(Suppl):S47–S49.
- Gusev MG, Lein GA, Alzoba SV. Advantages of the Marlo anatomical socket (MAS) for transfemoral prosthesis. *Genij Ortopedii*. 2020;26(3):359–63.
- Fatone S, Caldwell R. Northwestern University Flexible Subischial Vacuum Socket for persons with transfemoral amputation–Part 1: Description of technique. *Prosthet Orthot Int*. 2017;41(3):237–45.
- Fatone S, Caldwell R. Northwestern University Flexible Subischial Vacuum Socket for persons with transfemoral amputation–Part 2: Description and preliminary evaluation. *Prosthet Orthot Int*. 2017;41(3):246–50.
- Köhler TM, Blumentritt S, Braatz F, Bellmann M. The impact of transfemoral socket adduction on pelvic and trunk stabilization during level walking—a biomechanical study. *Gait Posture*. 2021;89:169–77.
- Schuch CM. Modern above-knee fitting practice (a report on the ISPO workshop on above-knee fitting and alignment techniques, May 15–19, 1987, Miami, USA). *Prosthet Orthot Int*. 1988;12(2):77–90.
- Tan JM, Halford GRJ, Lukin M, Kohler F. Recommendations from the ISPO lower-limb COMPASS: patient-reported and performance-based outcome measures. *Prosthet Orthot Int*. 2023;47(1):13–25.
- Hanspal RS, Fisher K, Nieveen R. Prosthetic socket fit comfort score. *Disabil Rehabil*. 2003;25(22):1278–80.
- Legro MW, Reiber GD, Smith DG, del Aguila M, Larsen J, Boone D. Prosthesis evaluation questionnaire for persons with lower limb amputations: Assessing prosthesis-related quality of life. *Arch Phys Med Rehabil*. 1998;79(8):931–8.

23. ATS Statement. Guidelines for the six-minute walk test. *Am J Respir Crit Care Med*. 2002;166(1):111–7.
24. Resnik L, Borgia M. Reliability of outcome measures for people with lower-limb amputations: distinguishing true change from statistical error. *Phys Ther*. 2011;91(4):555–65.
25. Balk EM, Gazula A, Markozannes G, Kimmel HJ, Saldanha IJ, Resnik LJ, et al. Lower limb prostheses: measurement instruments, comparison of component effects by subgroups, and long-term outcomes. Comparative Effectiveness Review No. 213. Rockville (MD): Agency for Healthcare Research and Quality; 2018. AHRQ Publication No. 18-EHC017-EF.
26. Dite W, Temple VA. A clinical test of stepping and change of direction to identify multiple falling older adults. *Arch Phys Med Rehabil*. 2002;83(11):1566–71.
27. Sawers A, Kim J, Balkman G, Hafner BJ. Interrater and test-retest reliability of performance-based clinical tests administered to established users of lower limb prostheses. *Phys Ther*. 2020; 100(7):1206–16.
28. Dite W, Connor HJ, Curtis HC. Clinical identification of multiple fall risk early after unilateral transtibial amputation. *Arch Phys Med Rehabil*. 2007;88(1):109–14.
29. Ramstrand N, Nilsson KA. Validation of a patient activity monitor to quantify ambulatory activity in an amputee population. *Prosthet Orthot Int*. 2007;31(2):157–66.
30. Whitehead AL, Julious SA, Cooper CL, Campbell MJ. Estimating the sample size for a pilot randomised trial to minimise the overall trial sample size for the external pilot and main trial for a continuous outcome variable. *Stat Methods Med Res*. 2016; 25(3):1057–73.