Al-Azhar International Medical Journal

Volume 4 | Issue 10 Article 17

2023

Section: Rheumatology and Medical Rehabilitation

Symmetry of Body Weight Pressure Distribution on Sound Limb Foot of Unilateral Amputees During Walking

Maged Eissa
Agouza Rheumatology and Rehabilitation Center , Cairo , Egypt, magedabdullah89@gmail.com

Sameh Ahmed Fathy El Zayat
Rheumatology and Rehabilitation Department, Faculty of Medicine, Al-Azhar University, Cairo , Egypt

Mohamed Magdy Ghit
Rheumatology and Rehabilitation Department, Faculty of Medicine, Al-Azhar University, Cairo , Egypt

Bassem Gomaa
Rheumatology and Rehabilitation Department, Agouza rehabilitation center of armed forces ,Cairo , Egypt

How to Cite This Article

Eissa, Maged; Zayat, Sameh Ahmed Fathy El; Ghit, Mohamed Magdy; and Gomaa, Bassem (2023) "Symmetry of Body Weight Pressure Distribution on Sound Limb Foot of Unilateral Amputees During Walking," *Al-Azhar International Medical Journal*: Vol. 4: Iss. 10, Article 17.
DOI: https://doi.org/10.58675/2682-339X.1959

ORIGINAL ARTICLE

Symmetry of Body Weight Pressure Distribution on Sound Limb Foot of Unilateral Amputees During Walking

Maged Eissa [a,*], Sameh Ahmed Fathy El Zayat [b], Mohamed Magdy Ghit [b], Bassem Gomaa [c]

[a] Agouza Rheumatology and Rehabilitation Center, Cairo, Egypt
[b] Rheumatology and Rehabilitation Department, Faculty of Medicine, Al-Azhar University, Cairo, Egypt
[c] Rheumatology and Rehabilitation Department, Agouza Rehabilitation Center of Armed Forces, Cairo, Egypt

Abstract

Background and purpose: **Gait asymmetry represents one of the primary issues for individuals with unilateral amputations of the lower limbs in order to prevent excessive stress on the sound leg.**

Aim of the work: **To analyze pressure distribution through the foot of the sound limb to evaluate the mechanical risk factors in unilateral amputees.**

Patients and methods: **We included 30 subjects classified into 15 traumatic unilateral *trans*-femoral or *trans*-tibial amputees without advanced osteoarthritic changes or foot deformities and 15 normal individuals as a control group. All patients have undergone careful history-taking, including a sound limb investigation for skin integrity and sensation, muscle power, and joint range of motion, along with pressure distribution with my Walkway Tekscan device.**

Results: **A comparison study between the two groups in the examined population demonstrated a significantly significant decrease in S-A surface area in the amputated limb in the case group in comparison with the control group (*P* 0.001). Moreover, we discovered a highly significant decrease in SA force in the amputated leg in the case group in comparison with the control group (*P* 0.001). Furthermore, comparative research between the two groups demonstrated a very significant increase in SA area% change and S-A force% change in the case group in comparison with the control group (*P* 0.001).**

Conclusion: **To conclude, our study found that when comparing cases to controls, both sound limb to amputation area and force % changes were considerably larger in cases, indicating overloading on the sound limb when walking.**

Keywords: Amputees, Pressure, Symmetry, Walking

1. Introduction

Amputees of the lower limb are significantly more active now than they were in previous decades. Amputees' capacity to adjust to the partial loss of their lower legs has improved as a result of amputation procedures, after-surgery rehabilitation, and prosthetic improvements. In unilateral lower-extremity amputees, asymmetry is connected to adaptation to the loss of function of one or more joints. Previous studies have observed muscle asymmetry, with atrophy on the amputation side and hypertrophy on the intact leg, as well as loading asymmetry, with the intact limb having a larger vertical ground response force than the prosthetic extremity.

There are around 2 million people living with limb loss in the United States (1). The most common reasons for limb loss include trauma (45%), vascular diseases (54%), which include peripheral artery disease and diabetes, and cancer (<2%). Up to 55% of diabetics who have had a lower extremity amputation may need a second leg amputation within the next 2–3 years.[1]

Accepted 18 May 2023.

* Corresponding author.
E-mail address: magedabdullah89@gmail.com (M. Eissa).

https://doi.org/10.58675/2682-339X.1959

The fundamental objective of therapy for amputees of the lower limbs is to re-establish as much of their normal gait as possible. The most appropriate components should be used in prosthetic systems to facilitate normal gait function. Gait asymmetry is a key issue for those who have had a unilateral lower extremity amputated in order to minimise undue stress on the sound limb.[2]

Asymmetrical elements of amputee gait have been described using kinematic and temporal data. Temporal variables such as stride length, cycle length, and stance time for *trans*-tibial and *trans*-femoral amputees have demonstrated a longer stance time on the intact limb due to a reluctance or inability to spend more time in single support on the prosthetic limb, and thus a shorter swing time on the intact limb to maintain walking speed.[3]

This study was carried out to examine the mechanical risk factors in unilateral amputees by evaluating pressure distribution through the foot of the sound limb.

2. Patients and methods

2.1. Patients

In our case-control research, 30 people participated.

Patients were picked up from the Armed Forces Physical Medicine, Rheumatology, and Rehabilitation Centre in Cairo.

Age: 18–60, Sex: men and females, traumatic amputation, and one limb amputation (*Trans*-femoral or *Trans*-tibial) were the inclusion criteria.

Exclusion criteria included surgery on a sound limb, diabetes, vascular disorders, peripheral artery illnesses, cancer, and congenital limb loss.

This research involved thirty patients. They were split into two groups: 15 traumatic unilateral *trans*-femoral or *trans*-tibial amputees without advanced osteoarthritic alterations or foot deformities and 15 healthy controls comprised the case group.

2.2. Methods

Patients underwent the following procedures: meticulous history taking, complaint, assessment of other systems, prior history, drug intake, surgical procedure or blood transfusion, and current medication.

My Walkway Tekscan gadget was used to do a thorough limb evaluation for skin integrity and feeling, muscle strength, joint range of motion, and pressure distribution.

Written informed consent was given by each patient.

2.3. Statistical analysis

Data entry, processing, and statistical analysis have been performed using SPSS 25. It was decided to use the tests of significance (Mann-Whitney, χ^2, and Spearman's correlation).

3. Results

The 30 participants investigated were divided into 15 traumatic unilateral *trans*-femoral or *trans*-tibial amputees without advanced osteoarthritic alterations or foot deformity and 15 controls.

Patient age and Sex ($P > 0.05$) were not significantly different between the two groups, according to comparative examinations (Table 1).

Comparative investigations between the two groups demonstrated no statistically significant differences in the degree and laterality of amputation or sound limb ($P > 0.05$) (Table 2).

Comparative examinations between the two groups found that there was no significant change in S-A average pressure in both amputee and sound limbs ($P > 0.05$). The S-A surface area in the severed leg (P 0.001) was significantly reduced in the case group. S-A surface area in the sound limb ($P > 0.05$) did not change significantly. A highly significant drop in SA force in the severed leg (P 0.001) has

Table 1. Age and sex comparisons between cases and controls.

Variable	Case ($n = 15$)	Control ($n = 15$)	P value
Age	34.3 ± 13.1	30.3 ± 13.9	0.405[a]
Sex			
Male	11 (73.3)	12 (80)	1.000[b]
Female	4 (26.7)	3 (20)	

The mean ± standard is given, while numbers (percentages) are used for qualitative variables.

[a] Mann-Whitney test.

[b] Chi-Square test, for quantitative variables.

Table 2. Age and sex comparisons between cases and controls.

Variable	Case ($n = 15$)
Level of amputation	
TT	10 (66.7)
TF	5 (33.3)
Amputee limb	
Right	4 (26.7)
Left	11 (73.3)
Sound limb	
Right	11 (73.3)
Left	4 (26.7)

Data described as number (percentage).

Table 3. Comparison between cases and controls regarding SA Average.

Variable	Case ($n = 15$)	Control ($n = 15$)	P value
Average. pressure A	705 (670–744)	773 (688–805)	0.065
Average pressure S	713 (631–733)	745 (673–788)	0.068
Area A	130 (111–154)	177 (166–198)	0.000
Area S	179 (166–189)	177 (157–189)	0.709
Force A (1000)	87.1 (82.6–101.2)	136.7 (115–152.8)	0.000
Force S (1000)	124.3 (115.2–131.9)	126.9 (112.4–140.8)	0.310
SA pressure % change	−0.8 (−4.1-3.2)	−3.5 (−5.5 to −1.4)	0.290
SA area % change	40.4 (29.7–48.9)	−3.4 (−7.1–1.8)	0.000
SA force % change	34.3 (18.2–48.9)	−7.4 (−10.6–0.7)	0.000

Pressure, area, forces with their percent changes.
Data described as median (25th-75th percentiles).

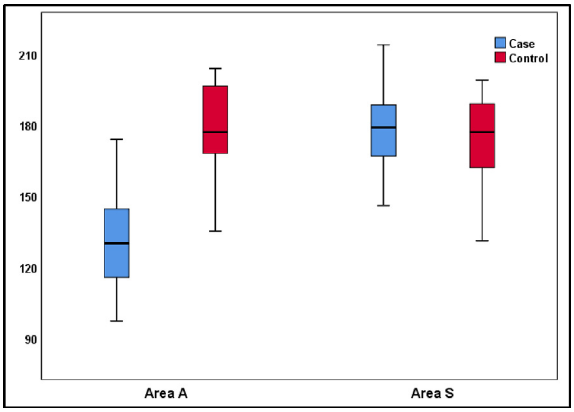

Fig. 1. Distribution of Area A and Area S between cases and controls.

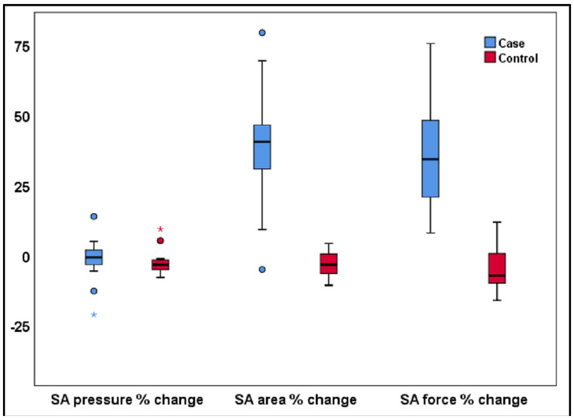

Fig. 3. Distribution of SA pressure, area and force % changes between cases and controls.

been observed in the case group. In the sound limb ($P > 0.05$), there was not a statistically significant change in SA force. Both the SA area% change and the S-A force% change (P 0.001) were significantly higher in the case group. In terms of SA pressure% change ($P > 0.05$), there wasn't a significant difference (Table 3).

Association tests on a case group of patients revealed a non-significant association between SA pressure, area, and force% changes and Sex ($P > 0.05$). The level of amputation ($P > 0.05$) in the case group did not significantly correlate with changes in SA pressure, area, or force%. There wasn't a statistically significant link between SA pressure, area, or force% alterations and amputee limb side ($P > 0.05$) in the case group. There wasn't a statistically significant link between the side of the

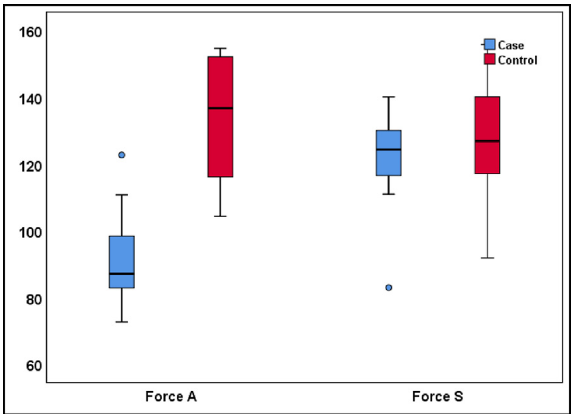

Fig. 2. Distribution of Force A and Force S between cases and controls.

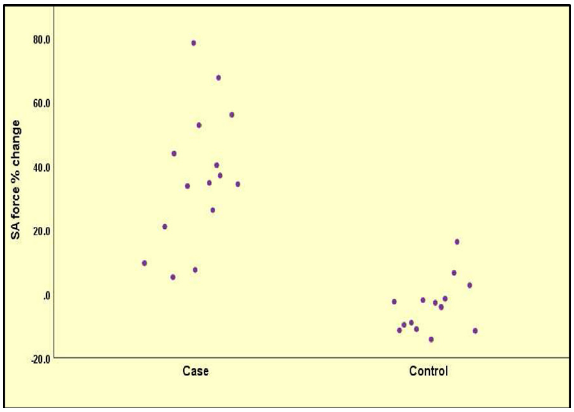

Fig. 4. Distribution of SA force % changes between cases and controls.

Table 4. Comparison of SA pressure, area and force % changes regarding sex, level of amputation, amputee limb, sound limb and their correlation with age within cases only.

Variable	SA pressure % change	SA area % change	SA force % change
Sex			
Male ($n = 11$)	−0.8 (−4.1–0.3)	40.4 (21.2–48.9)	30.1 (10.4–48.9)
Female ($n = 4$)	0.2 (−4.3–4)	40 (33.9–47)	36.9 (34–46.5)
P value	0.794	0.695	0.361
Level of amputation			
TT ($n = 10$)	0.1 (−2.4–3.2)	36.1 (21.2–48.9)	26.7 (10.4–48.9)
TF ($n = 5$)	−2.8 (−4.1 to −2.1)	40.9 (40–43.9)	35.7 (34.3–47.2)
P value	0.327	0.327	0.221
Amputee limb			
Rt ($n = 4$)	−1.4 (−3.5–0.1)	44.4 (38.1–59.1)	41.6 (33.3–59.2)
Lt ($n = 11$)	−0.8 (−5.7–4.4)	40.4 (21.2–43.9)	30.1 (10.4–47.2)
P value	0.602	0.361	0.240
Sound limb			
Rt ($n = 11$)	−0.8 (−5.7–4.4)	40.4 (21.2–43.9)	30.1 (10.4–47.2)
Lt ($n = 4$)	−1.4 (−3.5–0.1)	44.4 (38.1–59.1)	41.6 (33.3–59.2)
P value	0.602	0.361	0.240
Age			
r	0.236	−0.272	−0.324
P value	0.396	0.326	0.239

r = Spearman correlation coefficient.
Data described as median (25th-75th percentiles).

sound limb ($P > 0.05$) and changes in SA pressure, area, or force% in the case group. Age and SA pressure, area, and force% changes ($P > 0.05$) in the case group did not significantly associate (Figs. 1–4, Table 4).

4. Discussion

This was case-control research with 30 people divided into 15 traumatic unilateral *trans*-femoral or *trans*-tibial amputees without advanced osteoarthritic alterations or foot deformities and 15 control persons.

Plantar pressure analysis yields a wealth of data that may be used to aid in the diagnosis of lower limb diseases, footwear design, body biomechanical faults, prevention of musculoskeletal impairments, and other applications.[4]

This study's objective was to assess and analyze plantar pressure and force distribution across the foot of people who have suffered traumatic lower extremity loss versus able-bodied people when walking. According to de Castro et al. (2014), people with lower limb amputation exhibit worse physical function scores than their able-bodied counterparts, indicating restrictions in conducting daily life activities and asymmetry in gait.[5]

We employed platform systems in our study, which are made up of a rigid, flat array of pressure sensing devices organised in a matrix arrangement and implanted in the floor to permit natural stride. For this kind of research, dynamic, static, and postural research can be employed. One of the benefits of utilising the platform type is that it is more convenient to use since it is level and fixed, but the patient must become acquainted to ensure that he is walking in his normal stride. Furthermore, foot contact with the centre of the sensing area is critical for precise findings.[4]

In our analysis, we discovered that the majority of *trans*-femoral amputations (33.3%) and *trans*-tibial amputations (66.7%) were carried out. According to the 2007 National Amputee Statistical Database (UK) (NASDAB), 50% of lower limb amputations are *trans*-tibial, and *trans*-femoral amputations account for 34%.

However, when other researchers examined the centre of pressure,[6,7] lower limb kinematics,[8] and joint moment,[3] they discovered an uneven pattern when the person with *trans*-femoral amputation walked.

Royer and Koenig (2005) discovered indications indicating the possibility of early knee joint deterioration in the sound limb, indicating stress on the sound limb when walking.[9]

In terms of SA pressure, area, and force% changes among the cases alone, we discovered no statistically significant difference between *trans*-femoral and *trans*-tibial amputation level, side, or Sex. This is consistent with Nolan et al., 2003.[10]

For *trans*-tibial or *trans*-femoral amputees, Nolan et al. (2003) found no significant association among prosthetic and intact extremities at the 5% level for any variable.[10]

In our investigation, we discovered that both sound limb to amputation area and force % changes were substantially larger in cases than in controls, with $P = 0.000$, indicating overloading on the sound limb when walking. The large change in surface area has an effect on the average pressure, which is reflected in the force. This is consistent with the findings of Nadollek et al., 2002, Nolan et al., 2003, Castro et al., 2014, Claret et al., 2019, Shojaei et al., 2019, Winiarski et al., 2021, Ichimura et al., 2022, and Kobayashi et al., 2023.

According to Nadollek et al., 2002, substantially greater weight was placed on the intact limb compared to the severed limb.[11]

According to Nolan et al., 2003, the larger stress on the intact extremity might be a technique used by amputees to acquire more temporal symmetry for walking quickly. This hypothesis may also explain why the intact extremity experiences a higher incidence of degeneration of the joints.[10]

Each of the participants also had a (non-significant) weight-bearing asymmetry favouring the limb that wasn't severed. The dynamic balance control ratio revealed that the contributions of both legs to balance control were significantly unequal.[12]

On the other hand, Schmid et al. (2005) found that there was an imbalance in both temporal and spatial dimensions of quantifying centre of pressure (CoP) patterns among the sound and the prosthetic leg[7].

According to Lloyd et al. (2010), four characteristics in the amputee group were asymmetrical in comparison with the control group. Asymmetry in knee flexion strength was only moderately correlated with the vertical ground response force of the intact limb, while asymmetry in knee extension strength was highly connected to asymmetry in the rate of knee adduction moment load.[13]

Castro et al. (2014) also reported that the thrust, braking, and propulsive peaks, as well as the braking and propulsive impulses, had been significantly reduced in the severed leg in comparison with the intact limb (P. 05) and able-bodied individuals (*P*. 05).[5]

The mean CoP distance, CoP velocity, and sway area all increased significantly (*P* 0.001, 0.001, and 0.007) for amputees, according to Claret et al., 2019. Amputees took an unbalanced position.[14]

Shojaei et al., 2019 also revealed that individuals with amputations had higher peak compression, medio-lateral (just during stand-to-sit), and anteroposterior shear forces than individuals without amputations, respectively, by 348 N, 269 N, and 217 N.[15]

Furthermore, Shojaei et al. (2019) determined that although the spinal loads in individuals with amputations were higher, such loads were often lower compared to the established threshold for spinal damage. A very slight rise in spinal loads during routine daily activities such as walking, sitting to standing, and standing to sitting, however, may offer an elevated risk of fatigue failure for spinal tissues due to the repeated nature of these activities.[15]

Winiarski et al. (2021) demonstrated that the symmetry function is a useful tool for finding areas of asymmetry and dominance of limbs during the walking cycle. According to the Symmetry Function, the pelvis and hip exhibited the biggest discrepancy between sides. The pelvis was asymmetrically tilted in the sagittal plane at 60% cycle time, achieving a maximum SF value of more than 25%.[16]

Ichimura et al. (2022) also showed that the COP trajectories of UTFA patients had much more lateral asymmetry and variability than those of healthy controls, but not anterior-posterior variability.[17]

Kobayashi et al., 2022 also observed that step frequency had substantial major impacts in various parameters (P 0.01). Peak ground reaction forces (GRF) and GRF impulse characteristics indicating strong primary impacts tended to decrease in magnitude as step frequency increased. Between the limbs, from 5% to 0% metronome frequency, the peak vertical GRF showed the most symmetrical values. With increasing step frequency, all factors that had a significant influence on the asymmetry ratio grew more asymmetric.[18]

Between people who had unilateral *trans*-femoral amputation and people with normal health, Kobayashi et al. (2023) found statistically significant differences in the asymmetry ratios for peak vertical ground reaction force, anterior-posterior ground reaction force, anteroposterior shear, as well as mediolateral shear. Patients who have a unilateral *trans*-femoral amputation continue to experience asymmetrical loads during double-limb stance.[19]

4.1. Conclusion

To conclude, our study found that when comparing cases to controls, both sound limb to amputation area and force % changes were considerably larger in cases, indicating overloading on the sound limb when walking.

Conflicts of interest

None.

References

1. Ziegler-Graham K, MacKenzie EJ, Ephraim PL, et al. Estimating the Prevalence of limb loss in the United States: 2005 to 2050. *Arch Phys Med Rehabil*. 2008;89:422–429.

2. Eshraghi A, Abu Osman NA, Karimi M, et al. Gait biomechanics of individuals with transtibial amputation: effect of suspension system. *PLoS One*. 2014;9:e96988.
3. Nolan L, Lees A. The functional demands on the intact limb during walking for active trans- femoral and trans- tibial amputees. *Prosthet Orthot Int*. 2000;24:117–125.
4. Abdul Razak AH, Zayegh A, Begg RK, et al. Foot plantar pressure measurement system: a review. *Sensors*. 2012;12: 9884–9912. https://doi.org/10.3390/s120709884.
5. Castro M P de, Soares D, Mendes E, Machado L. Plantar pressures and ground reaction forces during walking of individuals with unilateral transfemoral amputation. *Pharm Manag PM R*. 2014;6:698–707.e1. https://doi.org/10.1016/j.pmrj.2014.01.019.
6. de Castro MP, Soares D, Mendes E, Machado L. Center of pressure analysis during gait of elderly adult transfemoral amputees. *J Prosthet Orthot*. 2013;25:68. https://doi.org/10.1097/JPO.0b013e31828c04b0.
7. Schmid M, Beltrami G, Zambarbieri D, et al. Centre of pressure displacements in trans-femoral amputees during gait. *Gait Posture*. 2005;21:255–262. https://doi.org/10.1016/j.gaitpost.2004.01.016.
8. Sapin E, Goujon H, De Almeida F, et al. Functional Gait analysis of trans-femoral amputees using two different single-axis prosthetic knees with hydraulic swing-phase control: kinematic and kinetic comparison of two prosthetic knees. *Prosthet Orthot Int*. 2008;32:201–218.
9. Royer T, Koenig M. Joint loading and bone mineral density in persons with unilateral, trans-tibial amputation. *Clin Biomech*. 2005;20:1119–1125. https://doi.org/10.1016/j.clinbiomech.2005.07.003.
10. Nolan L, Wit A, Dudziñski K, et al. Adjustments in Gait symmetry with walking speed in trans-femoral and trans-tibial amputees. *Gait Posture*. 2003;17:142–151. https://doi.org/10.1016/S0966-6362(02)00066-8.
11. Nadollek H, Brauer S, Isles R. Outcomes after trans-tibial amputation: the relationship between quiet stance ability, strength of hip abductor muscles and gait. *Physiother Res Int*. 2002;7:203–214. https://doi.org/10.1002/pri.260.
12. Nederhand MJ, Van Asseldonk EHF, der Kooij H, et al. Dynamic Balance Control (DBC) in lower leg amputee subjects; contribution of the regulatory activity of the prosthesis side. *Clin Biomech*. 2012;27:40–45. https://doi.org/10.1016/j.clinbiomech.2011.07.008.
13. Lloyd CH, Stanhope SJ, Davis IS, et al. Strength asymmetry and osteoarthritis risk factors in unilateral trans-tibial, amputee gait. *Gait Posture*. 2010;32:296–300. https://doi.org/10.1016/j.gaitpost.2010.05.003.
14. Claret CR, Herget GW, Kouba L, et al. Neuromuscular adaptations and sensorimotor integration following a unilateral transfemoral amputation. *J NeuroEng Rehabil*. 2019;16:115. https://doi.org/10.1186/s12984-019-0586-9.
15. Shojaei I, Hendershot BD, Acasio JC, et al. Trunk muscle forces and spinal loads in persons with unilateral transfemoral amputation during sit-to-stand and stand-to-sit activities. *Clin Biomech*. 2019;63:95–103. https://doi.org/10.1016/j.clinbiomech.2019.02.021.
16. Winiarski S, Rutkowska-Kucharska A, Kowal M. Symmetry function – an effective tool for evaluating the gait symmetry of trans-femoral amputees. *Gait Posture*. 2021;90:9–15. https://doi.org/10.1016/j.gaitpost.2021.07.021.
17. Ichimura D, Hisano G, Murata H, et al. Centre of pressure during walking after unilateral transfemoral amputation. *Sci Rep*. 2022;12:17501. https://doi.org/10.1038/s41598-022-22254-5.
18. Kobayashi T, Koh MWP, Hu M, et al. Effects of step frequency during running on the magnitude and symmetry of ground reaction forces in individuals with a transfemoral amputation. *J NeuroEng Rehabil*. 2022;19:33. https://doi.org/10.1186/s12984-022-01012-8.
19. Kobayashi T, Koh MWP, Jor A, et al. Ground reaction forces during double limb stances while walking in individuals with unilateral transfemoral amputation. *Front Bioeng Biotechnol*. 2023;10:1041060.