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Hip extension power and abduction power asymmetry as independent predictors of walking speed in individuals with unilateral lower-limb amputation

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ABSTRACT

Background: Preferred walking speed (PWS) is an indicator of walking ability, prosthetic walking potential, and function following a lower-limb amputation (LLA). There is a link between lower-limb muscle performance and PWS in individuals with LLA. However, the ability of select hip muscle performance parameters to determine PWS in these individuals still needs to be thoroughly investigated.
Research question: Which hip muscle and joint torque parameters best determine PWS in persons with LLA?
Methods: Seventeen patients with LLA (6 transfemoral, 4 knee disarticulation, and 7 transtibial; 16 men, 1 woman; mean age ± standard deviation, 56 ± 15yr) participated in this cross-sectional study. Maximal joint torque and power were evaluated unilaterally, for both amputated and intact limbs, in isometric and isokinetic conditions during hip flexion/extension (60°/s and 180°/s) and abduction/adduction (30°/s and 90°/s). PWS was measured at habitual walking speed over a 10-m distance. Pearson's correlation coefficient was used to verify the degree of association between each torque parameter and PWS and multiple regression analysis was performed to identify the best predictors of PWS. The level of significance was $p < 0.05$.
Results: Correlations between hip muscle performance parameters and PWS were found in most cases ($r = 0.51–0.82$; $p \leq 0.036–0.0005$). The multiple regression model revealed that the best independent predictors of PWS were hip extension power at 180°/s on the amputated side ($r^2 = 0.672$; $p < 0.0005$) and the asymmetry of hip abduction power at 30°/s ($r^2 = -0.147$; $p < 0.008$), accounting together for 82% of the variance in PWS.
Significance: Lesser hip extension power on the amputated side and greater hip abduction power asymmetry between limbs are detrimental to PWS in persons with LLA. These muscle groups and performance parameters should be considered during gait rehabilitation to assist individuals with LLA in achieving functional waking speed.

1. Introduction

In general, individuals with a lower-limb amputation (LLA) walking with a prosthesis have reduced muscle strength on the amputated side due to structural loss and muscle atrophy, which in some cases may result in high levels of strength asymmetry [1,2]. In parallel, these individuals also show adaptive strategies during gait that aim to compensate the total or partial loss of the segment and the muscles involved at the ankle (transtibial amputation) and/or knee (transfemoral amputation or knee disarticulation) joints [3–5]. These compensations may be summarized by greater energy absorption and generation by the muscles involved at the hip joint on the amputated side (mainly by the hip extensors and abductors) in concert with the increased use of the intact limb, regardless of the level of amputation

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[5–8].

Hip extensor and abductor strength appear to play a prominent role in walking ability, especially in determining walking speed, since the extensors act primarily for forward propulsion of the body, whereas the abductors may act to avoid unnecessary movements in the frontal plane (e.g. Trendelenburg gait) during the stance phase [9,10], mainly in the absence or restriction of the musculature involved at the ankle and knee joints [6,7,11,12].

The preferred walking speed (PWS) is a reliable global gait performance metric obtained quickly, easily, safely and cheaply, in comparison with more comprehensive assessment tools, and can be used as a single-item assessment tool in populations with impaired mobility [13]. In addition, PWS is the most common parameter used in gait analysis (in both clinical and research settings) of individuals with LLA, is related with functional capacity and prosthetic walking potential in these individuals [4,14,15] and is also the most consistent outcome measure in studies that investigated exercises to improve gait performance in persons with LLA [16]. In fact, impaired mobility has been identified as the most prevalent determinant of quality of life in individuals with a vascular amputation above pain, progression of disease, and depression [17].

Previous studies have demonstrated positive correlations between hip extensor or abductor strength and maximum walking speed, or PWS, in persons with a transfemoral or transtibial amputation [7,11,18]. However, the relationship between hip strength and walking speed is not yet well established in this population due to some methodological limitations of studies. For example, in the studies of Powers et al. [18] and Nadollek et al. [7], hip extensor and/or abductor torque or force were measured only in isometric conditions, without individuals using their prostheses, whereas in the study of Raya et al. [11] the strength of hip extensors and abductors, only on the amputated side (without prosthesis), was measured indirectly by scored functional tests (i.e. pelvis-raise against gravity in supine and side lying position, respectively). While muscle strength is important, muscle power may be more determinant of walking speed as it contributes to the ability to accelerate body mass during stance and advance the swing limb in a timely manner [6,9]. In addition, we believe that the use of the prosthesis during strength and power assessments may increase the ecological validity of the results.

Muscle performance asymmetries between amputated and intact limbs, mainly for the hip abductors [6,7], and low torque and power capacity, mainly for the hip extensors on the amputated side [6,11,18], may be associated with impaired walking speed in persons with LLA [9,19], yet they have not been well studied. In fact, new evidence about the relationship between hip muscle performance and PWS can aid the clinical rehabilitation of strength and power in individuals with LLA and inform the development of active prosthetics that augment muscle torque and power deficits to restore gait symmetry and PWS. Therefore, the aim of this study was to identify the ability of hip muscle performance parameters to determine PWS in individuals with LLA. We hypothesized that hip extensor power on the amputated side and asymmetry of hip abductor power are the main independent predictors of PWS in persons with LLA.

2. Methods

2.1. Participants

Participants were recruited at a physical rehabilitation center between April 2016 and July 2017.

Patients aged 18 years or older, of both sexes, with a transtibial, knee disarticulation or transfemoral amputation of any nature, who used their prosthesis for at least 1 month were included in the study. Patients older than 80 years, or with inferior to transtibial amputation or superior to transfemoral amputation, or with neurological, cardiovascular, respiratory or osteomyoarticular impairments, or who were unable to complete the walking test without the use of mobility aids were excluded from the study. All patients participated voluntarily, were informed about all study procedures and signed the informed consent form approved by the local Ethics Committee.

Table 1
Demographic and clinical characteristics of the participants.

	Mean (SD)	Range
Demographic		
Male:Female (n)	16:1	
Age (years)	56 (15)	22–72
Height (m)	1.71 (0.09)	1.56–1.93
Body mass (kg)	80.5 (16.6)	56–121
Clinical		
Etiology of amputation (n)	Vasc.:9/Traum.:8	
Level of amputation (n)	TF:6/KD:4/TT:7	
Prosthetic foot (n)	Flex:9/SACH:8	
Time since amputation (months)	59 (30)	20–108
Time since prosthetic fitting (months)	5 (3)	1–12
Preferred walking speed (m/s)	0.70 (0.19)	0.33–1.03

Vasc.: vascular, Traum.: traumatic, TF: transfemoral, KD: knee disarticulation, TT: transtibial.

Demographic and clinical characteristics of the participants are presented in Table 1.

The etiology of amputations was traumatic in 8 patients and vascular in 9 patients. Among the patients, 9 were using a prosthetic Flex-foot and 8 a prosthetic solid-ankle cushion heel (SACH) foot. All individuals with a transfemoral or knee disarticulation amputation were using passive mechanical knee prostheses.

2.2. Procedures

Data collection was performed at two visits separated by 2–5 days. At the first visit, demographic and clinical data were obtained followed by familiarization of the participants to the 10-m walk test, and familiarization to the isometric and isokinetic strength tests that were performed unilaterally, for both amputated and intact limbs, on an isokinetic dynamometer (System PRO 4, Biodex®, USA). At the second visit, the same walking and strength evaluation procedures were performed to obtain study data.

In order to obtain PWS, each participant was instructed to walk in a straight line on a level, smooth and non-slip 15-m walkway with marks at 0, 2.5, 12.5, and 15 m of distance. The walk began from a static start and the participant accelerated over the initial 2.5 m, walked at the habitual speed at which he/she safely and comfortably performs his/her daily activities over the middle 10-m distance, and decelerated over the final 2.5 m [15,20,21]. A manual stop watch was used to obtain the time required to walk the middle 10-m distance to calculate PWS. This procedure was performed three times with each participant and, when necessary, recovery was given between trials. The 10-m walks preceded strength and power measurement and served as a warm up for these assessments.

For isometric hip flexion and extension strength assessments participants were positioned in a supine position at 60° of hip flexion, and isokinetic strength and power assessments were performed in the same position at angular velocities of 60°/s and 180°/s (Fig. 1). For isometric hip abduction and adduction strength assessments the participants were positioned in lateral decubitus at 15° of hip abduction, and isokinetic strength and power assessment was performed in the same position at angular velocities of 30°/s and 90°/s (Fig. 1). The dynamometer axis of rotation was carefully aligned with the hip joint axis of rotation for each joint action by an experienced investigator [22–24]. The trunk, hip and contralateral limb were stabilized by adjustable straps.

After being positioned in the isokinetic dynamometer, gravitational correction was performed, and participants performed three practice submaximal voluntary contractions prior to each evaluation protocol.

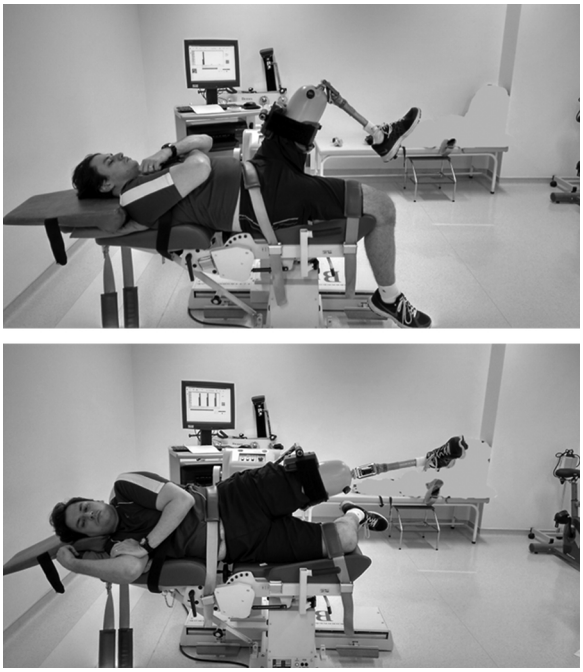

Fig. 1. Positioning used for hip flexion/extension (upper) and abduction/adduction (bottom) strength and power assessments. Photo used with participant permission.

Then, three maximal voluntary isometric contractions lasting 5 s each were performed with a 30-s rest interval between them. Then, 5 maximal voluntary isokinetic contractions were performed at 30°/s, 60°/s, and 90°/s velocities and 10 contractions at 180°/s speed were performed for respective movement patterns. The sequence of the evaluation protocols was randomized by lower limb (left and right), movement pattern (extension/flexion and abduction/adduction), and contraction speed (isometric, isokinetic at lower speed and isokinetic at higher speed). All individuals were verbally encouraged throughout the test to perform the muscle contraction "as strong and fast as possible". A minimum interval of 2 min rest was provided between each protocol and 5 min rest interval was given between each limb evaluation.

2.3. Data analysis

Strength (highest torque value among repetitions) and average power (total work / total time for the entire set) were obtained for each pattern of muscle contraction and normalized to body mass. The asymmetry index (AI) was calculated according to Eq. (1) [19].

$$AI\ (\%) = \left(\frac{|weak\ leg\ value - strong\ leg\ value|}{strong\ leg\ value} \right) \times 100 \quad (1)$$

PWS was calculated by dividing the distance covered during each 10-m walking trial by the time to cover this distance. The average value of three trials was used for subsequent analysis.

2.4. Statistical analyses

For correlation analyses between the participants demographic, clinical, hip muscle performance parameters and the PWS, a sample size of 17 was sufficient to detect a significant (two-sided) Pearson correlation coefficient > 0.482 with a power of 80%.

Normality of data distribution was confirmed using the Shapiro-Wilk test and Q-Q plots. Two-way repeated measures multivariate analysis of variance (MANOVA) was used to determine if peak torque and average power differed between amputated and intact limbs across isokinetic test velocities (side vs velocity interaction). When a significant side vs velocity interaction existed, it was followed with separate repeated measures analysis of variance (ANOVA) tests for each pattern of muscle contraction (hip flexion, extension, abduction and adduction) and contrasts to break down interactions. One-way repeated measures MANOVA was used to determine if AI of peak torque and average power varied across isokinetic test velocities, and significant effects were followed with dependent t-tests to test for contraction velocity differences, with Holm adjustment as appropriate. Pearson's correlation coefficients were used to separately correlate the muscle performance parameters (i.e. peak torque, average power and AI in each pattern and speed of movement) and demographic (i.e. age) and clinical characteristics (i.e. level of amputation, time since amputation and time since prosthetic fitting) with PWS. Stepwise regression analyses using a forward stepwise procedure were performed with all variables to identify the best predictors of PWS. Cross-validation (Stein's formula) was performed to assess the generalizability of the predictive model. The level of significance was $p < 0.05$. All analyzes were performed using a statistical software package (SPSS 18.0, Chicago).

3. Results

The results of the comparisons of the hip muscle performance parameters between the amputated and intact limbs and AI across isokinetic test velocities are presented in Fig. 2.

A significant side vs velocity interaction was achieved for hip flexion ($p = 0.018$) and abduction ($p = 0.007$) peak torques, because the intact vs amputated limb difference was 5% greater for hip flexion at 60°/s than in the isometric condition ($p < 0.001$) and was 13% greater for hip abduction at 30°/s than in the isometric condition ($p = 0.011$). Peak torque differences between intact and amputated limbs (in favor of intact limb) were 25% for isometric hip flexion ($p < 0.001$), 30% for hip flexion at 60°/s ($p < 0.001$), 32% for hip flexion at 180°/s ($p < 0.001$), 19% for isometric hip extension ($p < 0.001$), 21% for hip extension at 60°/s ($p = 0.002$), 20% for hip extension at 180°/s ($p = 0.022$), 14% for hip abduction at 30°/s ($p = 0.020$) and 14% for hip abduction at 90°/s ($p = 0.039$).

There was a significant side vs velocity interaction for hip flexion average power ($p < 0.001$), because the intact vs amputated limb difference was 5% greater for hip flexion at 180°/s than at 60°/s ($p < 0.001$). Average power differences between intact and amputated limbs (in favor of intact limb) were 33% for hip flexion at 60°/s ($p < 0.001$), 38% for hip flexion at 180°/s ($p < 0.001$), 21% for hip extension at 60°/s ($p = 0.001$) and 20% for hip abduction at 30°/s ($p = 0.014$).

A significant effect of isokinetic test velocity was achieved for hip extension peak torque asymmetry ($p = 0.020$). Peak torque asymmetry was 45% and 53% higher for hip extension at 60°/s ($p = 0.035$) and at 180°/s ($p = 0.049$) than in the isometric condition, respectively.

Significant correlations between hip muscle performance parameters and the PWS were found in most cases (Tables 2 and 3). However, age ($r = -0.275$; $p = 0.286$), level of amputation ($r = -0.476$; $p = 0.054$), time since amputation ($r = 0.357$; $p = 0.210$) and time since prosthetic fitting ($r = -0.325$; $p = 0.220$) did not correlate significantly with the PWS.

The regression analysis revealed that the best independent predictors of PWS were the hip extension power at 180°/s on the amputated side ($r^2 = 0.672$) and the AI of hip abduction power at 30°/s ($r^2 = -0.147$), accounting together for 82% of the variance in PWS (Table 4). Cross-validation estimated that, when applied to the population of individuals with LLA, the model could explain 75% of the variance in the PWS.

4. Discussion

Our results support the initial hypothesis that hip extensor power on the amputated side and the AI of hip abduction power are the main

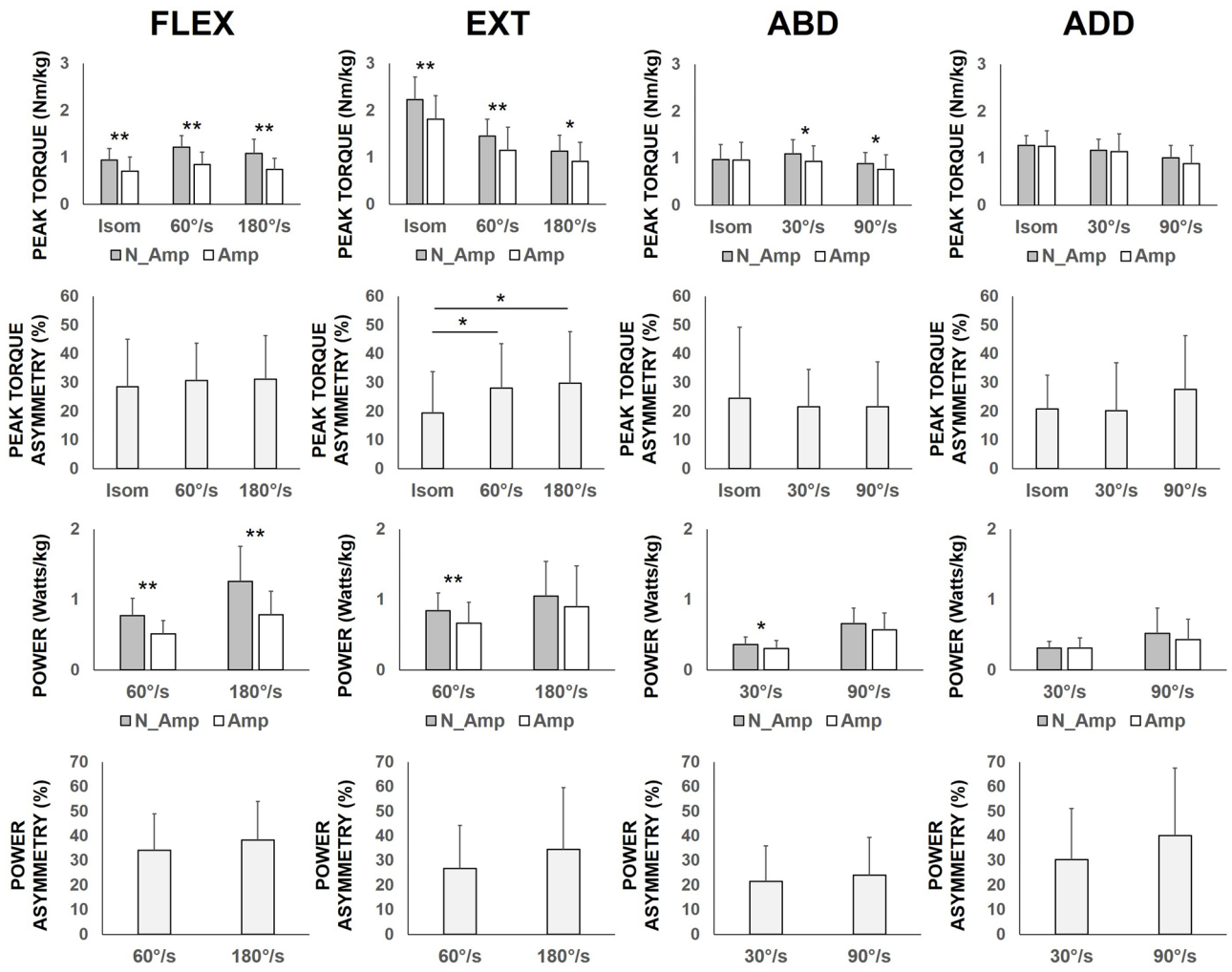

Fig. 2. Joint torque and asymmetry parameters (peak torque and power) of hip flexion (FLEX), extension (EXT), abduction (ABD) and adduction (ADD) in isometric and isokinetic conditions. N_Amp = non-amputated limb; Amp: amputated limb.

independent predictors of PWS in individuals with LLA. The hip extensor power at 180°/s on the amputated side was the best predictor of PWS, accounting alone for 67% of the total variance in PWS. Indeed, in the absence of ankle plantarflexors the hip extensors will be the primary muscle group that elicits forward translation of the body center of mass during the propulsive phase of stance for both transtibial and transfemoral amputations [3–6]. Furthermore, 180°/s is a normal peak angular velocity at the hip during walking supporting the idea that higher velocity contractions may be more appropriate for assessing function [25]. The hip abduction power asymmetry at 30°/s was also an independent predictor of PWS in the regression model as it alone accounted for another 15% of the total variance in PWS. Weakness of the hip abductors leads to asymmetrical gait and reduced ability to avoid unnecessary movements in the frontal plane (e.g. Trendelenburg gait) for maintenance of the body center of mass over the support limb during the stance phase and, ultimately, can lead to reduced PWS [6,7,9,26]. Therefore, isokinetic hip extension power and hip abduction power asymmetry, as identified here, can be used in combination as excellent muscle performance criteria in gait rehabilitation programs focused on increasing walking speed to a functional level in individuals with LLA [13].

The difference in the explanatory power of hip extension performance between the present study and previous studies [11,18] may have occurred due to methodological aspects. In the study of Powers et al. [18], the hip extension peak torque was obtained only isometrically and without the use of the prosthesis. In the study of Raya et al. [11], the hip extension strength was measured through a functional test (modified bridging maneuver) and without the use of the prosthesis, and gait performance was analyzed by distance covered in the 6-min walk test at the PWS. In our study, joint torque was measured directly in both isometric and isokinetic conditions with the individual using his/her prosthesis. Indeed, the use of the prosthesis during the evaluation increases the ecological validity, since persons with LLA use their prosthesis during walking by exerting forces at the socket (e.g. shear force) and at the point of ground contact. Another fact is that the joint power obtained during isokinetic contractions has been shown to be even more associated with walking speed than the peak torque, possibly because it is a measure that involves the application of torque in the context of movement [6,9]. Furthermore, in the present study PWS was obtained by 10-m walk test in contrast to 6-min walk test used in the study of Raya et al. [11]. The PWS may be influenced by the distance covered during the walk test, since at longer distances individuals tend to walk faster [27], or by the physical demands of each test. For example, the 10-m walk test may be more dependent on strength and power (shorter distance to cover) while the 6-min walk test may be more dependent on aerobic capacity (longer distance to cover). Taken together, these factors may have contributed to the greater explanatory ability of hip extension power observed in our study.

In contrast with a previous study [11], in our study, age, level of amputation and time since amputation neither correlated significantly with PWS nor were significant predictors in the regression analysis

Table 2
Correlation coefficients between hip muscle performance variables and preferred walking speed.

Variable	Walking Speed Amputated Limb	Intact Limb
Peak Torque (N.m. kg^{-1})		
Isometric flexion	**0.716 (p = 0.002)**	0.346 (p = 0.173)
Isokinetic flexion at 60°/s	**0.738 (p < 0.0005)**	**0.563 (p = 0.019)**
Isokinetic flexion at 180°/s	**0.660 (p = 0.004)**	**0.556 (p = 0.020)**
Isometric extension	**0.641 (p = 0.008)**	0.351 (p = 0.167)
Isokinetic extension at 60°/s	**0.751 (p < 0.0005)**	**0.659 (p = 0.004)**
Isokinetic extension at 180°/s	**0.648 (p = 0.004)**	**0.608 (p = 0.010)**
Isometric abduction	**0.673 (p = 0.004)**	0.467 (p = 0.059)
Isokinetic abduction at 30°/s	**0.755 (p < 0.0005)**	**0.509 (p = 0.037)**
Isokinetic abduction at 90°/s	**0.656 (p = 0.004)**	**0.568 (p = 0.018)**
Isometric adduction	**0.588 (p = 0.014)**	0.387 (p = 0.124)
Isokinetic adduction at 30°/s	**0.681 (p = 0.002)**	**0.633 (p = 0.006)**
Isokinetic adduction at 90°/s	**0.509 (p = 0.036)**	**0.689 (p = 0.002)**
Average Power (Watts. kg^{-1})		
Isokinetic flexion at 60°/s	**0.710 (p = 0.002)**	**0.549 (p = 0.022)**
Isokinetic flexion at 180°/s	**0.814 (p < 0.0005)**	**0.625 (p = 0.008)**
Isokinetic extension at 60°/s	**0.790 (p < 0.0005)**	**0.694 (p = 0.002)**
Isokinetic extension at 180°/s	**0.820 (p < 0.0005)***	**0.611 (p = 0.010)**
Isokinetic abduction at 30°/s	**0.667 (p = 0.004)**	**0.516 (p = 0.034)**
Isokinetic abduction at 90°/s	**0.624 (p = 0.008)**	**0.623 (p = 0.008)**
Isokinetic adduction at 30°/s	**0.805 (p < 0.0005)**	0.424 (p = 0.090)
Isokinetic adduction at 90°/s	**0.653 (p = 0.004)**	0.482 (p = 0.059)

Significant correlation ($p < 0.05$) are highlighted in bold.
*Significant independent predictor in the multiple linear regression model.

Table 3
Correlation coefficients between asymmetry index of hip muscle performance and preferred walking speed.

Variable	Walking Speed
Peak Torque Asymmetry (%)	
Isometric flexion	**−0.621 (p = 0.010)**
Isokinetic flexion at 60°/s	**−0.599 (p = 0.010)**
Isokinetic flexion at 180°/s	−0.243 (p = 0.348)
Isometric extension	−0.255 (p = 0.340)
Isokinetic extension at 60°/s	**−0.544 (p = 0.024)**
Isokinetic extension at 180°/s	−0.256 (p = 0.322)
Isometric abduction	0.002 (p = 0.992)
Isokinetic abduction at 30°/s	−0.390 (p = 0.122)
Isokinetic abduction at 90°/s	−0.449 (p = 0.070)
Isometric adduction	−0.253 (p = 0.327)
Isokinetic adduction at 30°/s	**−0.552 (p = 0.022)**
Isokinetic adduction at 90°/s	−0.169 (p = 0.516)
Average Power Asymmetry (%)	
Isokinetic flexion at 60°/s	**−0.599 (p = 0.012)**
Isokinetic flexion at 180°/s	**−0.582 (p = 0.014)**
Isokinetic extension at 60°/s	−0.458 (p = 0.064)
Isokinetic extension at 180°/s	−0.005 (p = 0.984)
Isokinetic abduction at 30°/s	**−0.590 (p = 0.014)***
Isokinetic abduction at 90°/s	−0.251 (p = 0.331)
Isokinetic adduction at 30°/s	−0.318 (p = 0.214)
Isokinetic adduction at 90°/s	−0.291 (p = 0.275)

Significant correlation ($p < 0.05$) are highlighted in bold.
* Significant independent predictor in the multiple linear regression model.

model. This discrepancy may have occurred due to the relatively higher functional capacity observed in our participants than in the participants of Raya et al. [11] (mean PWS: 0.70 m/s vs 0.31 m/s, respectively). In this sense, our results demonstrated that increasing age, higher level of amputation and shorter time since amputation were less associated with slow PWS than hip muscle weakness. Alternatively, the relatively small sample size employed in this study may have provided insufficient statistical power to detect these associations. Regardless, these demographic and clinical variables are still recognized as clinically important and should be treated as such.

Table 4
Stepwise multiple linear regression analysis.

	B	*B (SE)*	β
Step 1			
Constant	0.466	0.050	
Hip extension power at 180°/s on the amputated side	0.260	0.047	0.820**
Step 2			
Constant	0.602	0.059	
Hip extension power at 180°/s on the amputated side	0.225	0.039	0.709**
Bilateral asymmetry of hip abduction power at 30°/s	−0.005	0.002	−0.383*

$r^2 = 0.672$ for Step 1; $\Delta r^2 = 0.147$ for Step 2. *$p < 0.01$; **$p < 0.001$.

In general, an AI below 15% is considered acceptable for large muscle groups [19]. However, in the present study, on average, the AI of hip muscle performance exceeded 20% in all conditions with some conditions exceeding 30%, similar to previous studies [1,2]. It is expected that there will be an asymmetry between the amputated and intact limbs to compensate for the loss of function caused by the amputation, although whether the amputated or intact limb is stronger depends on physical activity history and resultant compensation [1,4,5,8]. The study by Nolan demonstrated that people with transtibial amputation who were sports active had better symmetry and strength of the amputated limb, whereas their inactive counterparts had substantial asymmetry due to weakness of the amputated limb [1]. Considering that in our participants, on average, the intact limb presented greater muscle performance than the amputated limb, the AI observed here agree with those observed in previous studies [1,2]. This is probably because while our participants were on average 59 months out from amputation, they were only 5 months out from using a prosthesis. They would have had significant atrophy on the amputated side during that time that 5 months of prosthesis use had not yet corrected. This result suggests that there is still a need to correct or minimize this asymmetry by strengthening these muscle groups to avoid functional loss and achieve good walking performance [28,16].

Although the sample size of this study is considered small by traditional sense, and includes only one female, it should be recognized that it is difficult to access and standardize assessment of individuals with LLA. Our sample was composed of 8 traumatic and 9 vascular patients. Epidemiological studies showed that in Brazilian rehabilitation centers, men, with a traumatic or vascular transfemoral or transtibial amputation are highly prevalent among persons with LLA [29–32]. The main causes of lower limb amputation are vascular diseases, mainly in men > 50 years old, followed by traumatic incidents, mainly in younger men. Thus, this study contributes importantly to the literature on strength and power asymmetries in the group of individuals most likely to experience LLA. However, a larger sample size would allow broader generalization of the results and more in-depth consideration of the effects of age, sex, level of amputation, cause of amputation, time since amputation and time since prosthetic fitting on PWS. Regarding lower limb comparisons, future studies that include a control group of non-disabled individuals could reinforce the results of the present study and provide a benchmark for evaluation of strength, power, and asymmetry. It should be recognized that PWS is only one measure of function, and future studies may test the association between muscle performance parameters and self-reported mobility limitation and disability, gait performance, and quality of life in people with LLA.

In conclusion, hip extension power on the amputated side at the highest isokinetic speed and the asymmetry of hip abduction power at lower isokinetic speed are the main independent predictors of PWS in individuals with LLA. Furthermore, asymmetry of hip strength and power in these individuals varied between 20%–30%, in which the amputated limb was weaker than the intact limb. Therefore, hip flexor,

extensor and abductor power, especially on the amputated side, and asymmetry of hip abductor power may be useful muscle performance parameters to evaluate and strengthen during gait rehabilitation in order to restore functional walking speed and, consequently, improve the quality of life of individuals with LLA.

Declarations of interest

None.

CRediT authorship contribution statement

Luciano F. Crozara: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing - original draft, Writing - review & editing. **Nise R. Marques:** Conceptualization, Methodology, Writing - review & editing. **Dain P. LaRoche:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Alessandro J. Pereira:** Conceptualization, Resources, Writing - review & editing. **Francine C.C. Silva:** Conceptualization, Methodology, Resources, Writing - review & editing. **Roberta C. Flores:** Conceptualization, Methodology, Resources, Writing - review & editing. **Spencer L.M. Payão:** Conceptualization, Methodology, Project administration, Writing - review & editing, Supervision, Funding acquisition.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.gaitpost.2019.03.033.

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