Original Article

The Effects of Isokinetic Hip Muscles Training on Gait Performance in Above-Knee Amputees: A Quasi-Experimental Study

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Background: Hip muscle strengthening was recommended for the above-knee amputee patients and expected gait correction. However, effectiveness of this training was not clearly described.

Objective: To evaluate the effect of hip muscles strengthening exercise on gait performance in the above knee amputees.

Materials and Methods: The unilateral above-knee amputees aged between 25 to 70 years old were invited into the study. All participants were K level 2 to 4 and independent without gait aid. Exercise program included isokinetic training of hip muscles of the amputated leg was performed in the rehabilitation center twice a week for three weeks. Outcome measures included pre- and post-exercise gait analysis and peak torque of hip muscles of the amputated leg.

Results: Eight subjects were included in the present study. Gait analysis showed no significant change between pre- and post-exercise of comfortable walking speed, step length, and cadence ($p>0.05$). There was a significant reduction (50%) in pelvic tilting amplitude ($p<0.05$). Post-exercise mean peak torque of the all hip muscles significantly increased from pre-exercise in all hip muscle groups.

Conclusion: A 3-week isokinetic training program of hip muscles improved hip strength and pelvic control during gait. However, there was no significance change of gait speed, step length, and cadence.

Keywords: Isokinetic, Hip muscle strengthening, Gait analysis, Above knee amputee

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Limb amputation is an important health problem in Thailand, with an estimated 50,000 patients that lose their legs each year[1]. It impacts the socioeconomic situation. Road traffic accident is the most common causes of amputation. Diabetes mellitus and arterial occlusion are increasing incidences of limb loss. In Thailand, below knee amputation is the major type of amputees with about 60% of the patients while above knee amputation is about 30%. The rest are below ankle and hip disarticulation level.

After patients had undergone amputate limbs, their ability to do daily living tasks is limited and their quality of life is affected[2]. Most of them have gait problems, such as speed reduction, asymmetrical step length, and prolong double support time, etc. From the study of Raetai et al[3], the above knee amputees demonstrated a reduced comfortable walking speed of 70% when compared with healthy subjects. Level of amputation was found to be key factor of ambulatory capability. Sansam et al[4] reported above knee and higher amputation casualties tend to have poor walking efficacy compared to below knee amputees. Many possible theories can explain this abnormality. The weakness of hip muscles is one of a negative predictor of walking ability. Croisier et al[5] studied hip muscles strength by isokinetic dynamometer in

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unilateral amputees and found significant reduction in hip muscle strength (20% to 30% compared with intact limb). Mostly affected muscle are the hip abductor and hip extensor groups.

In prosthetic service, the current practice when amputees come to get prosthetic fitting is to provide them with a home program of general exercise and prosthetic gait training based upon their specific needs. Hip muscle strengthening is the most common prescription for above knee amputees because these muscles group play as majority control of prosthetic leg and make better gait performance. A previous study(6) evaluated a 10-week isokinetic training of hip muscles on persons with lower limb amputation and found that some could run post training. Another study(7) found that hip strengthening exercise program with gait re-education improves walking performance in transfemoral amputees. A systematic review by Wong et al(8) suggested the hip strengthening exercise as a grade B recommendation. However, there is a lack of evidence about the effect of hip strengthening exercise on gait performance.

There are three types of strengthening methods, isometric, isotonic, and isokinetic. Most exercise programs use the isometric and isotonic methods because they are available in almost every hospital. However, the exercise techniques are difficult to do and less effective for above-knee amputees, especially in short stump and frail amputees. Using the isokinetic method, the targeted muscle can be trained more effectively than with the other methods. However, based on current evidences, there is no gold standard training program for amputees. The aim of the present study was to evaluate the effects of three weeks of isokinetic training of hip muscles on gait performance in unilateral above-knee amputees.

Materials and Methods

The unilateral above knee amputees who sought for medical consultation in rehabilitation medicine unit between June 2016 and December 2016 were invited into the study. The authors included patients with ages ranging from 25 to 70 years who had enough stump length (at least 15 centimeters), had already used their current prosthesis for more than three months, were able to walk without gait aid, and were without any limitation on their sound limb. Their functional level was determined as K2 to K4. Subjects who had stump pain, infection, wound, or any medical condition that affect walking such as cardiovascular, pulmonary, and neurological diseases were excluded from the present study. Participants were informed about study and signed informed consents. The present research was approved by the Ethics Committee of Faculty of Medicine, Prince of Songkla University. EC number was 59-023-11-1.

The sample size was calculated based on a study in Sweden(7), using the following "two dependent means" formulation. The calculated sample size number was eight participants.

Instruments and procedure

Tailgait(9) system was used to measure the gait parameters. The participants walked at a comfortable speed in a 10-meter walkway for three sessions. The CON-TREX was used for the hip muscle strength measurements(10). For the hip flexors-extensors strength evaluation(11), participants were in the supine position. For the hip abductors-adductors strength evaluation, participants were in a side-lying position with the amputated limb on the top. Participants performed two sets of ten repetitions at an angular velocity of 60 degrees per second.

Intervention

Participants were informed about the study and signed informed consents before entering study. They attended an isokinetic training twice weekly at the hospital for three weeks. The individual maximum muscle strength, the mean peak torque, was determined by isokinetic dynamometer (CON-TREX) before the first training session and one day after the last training session. The training program started with hip flexion and extension. The participants were placed in the supine position on a table. A 5-minute warm-up in the continuous passive movement (CPM) mode was followed by concentric ballistic exercises where two sets of ten repetitions at an angular velocity of 60 degrees per second were done. Then the participants rested for one minute, followed by two sets of ten repetitions at an angular velocity of 120 degrees per second. Lastly, a closing session of CPM for five minutes was done. For hip abduction and adduction, participants were positioned lying on their side with the amputated limb on the top. A break of ten minutes was allowed between muscle groups training to avoid fatigue. It was suggested that all participants continue the same activity and exercise, then record if there was change during study period.

The primary outcome was comfortable-walking speed. The secondary outcomes were gait parameters, including step length, step time, percentage of single support, percentage of double support, percentage of stance phase, and percentage of swing phase.

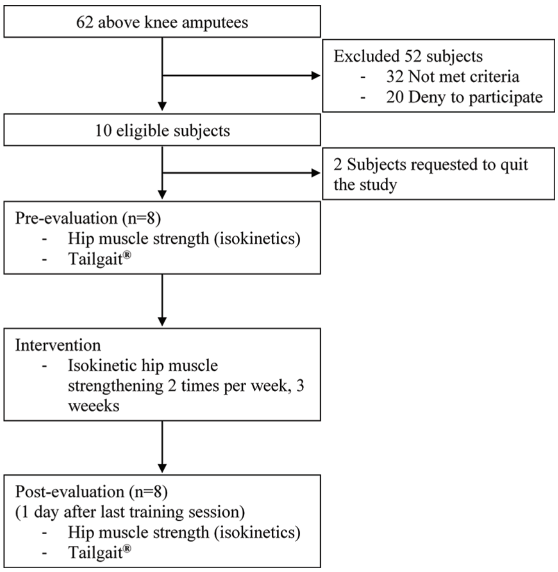

Figure 1. Methodology.

Table 1. Baseline characteristics (n=8)

	n (%)
Cause of amputation	
Traumatic	5 (62.5)
Others	3 (37.5)
Side of amputate limb	
Right leg	3 (37.5)
Left leg	5 (62.5)
Time post amputation	
<1 year	2 (25.0)
1 to 5 years	2 (25.0)
>5 years	4 (50.0)
No of current prosthesis	
1st prosthesis	2 (25.0)
2nd prosthesis	1 (12.5)
≥3rd prosthesis	5 (62.5)
Length of stump	
Standard	1 (12.5)
Long	7 (87.5)

Pelvic movement was determined by gyro meter. The outcome measurements were determined by an experience therapist who was trained in isokinetic training for five years. All participants were assessed before starting the first isokinetic session and one day after the last training session. All parameters were analyzed with R software, version 3.2.2 (R Core Team, Vienna, Austria) and SPSS Statistics software, version 10.0 (SPSS Inc., Chicago, Ill, USA). Baseline characteristic data were reported in mean and standard deviation. Each parameter of pre- and post-training was compared with paired t-test (muscle strength, gait speed, cadence, step length, and time) and Wilcoxon signed rank test (time of gait cycle, kinematic parameters, and prosthetic or sound limbs spatiotemporal parameters), based on the data distribution pattern. The level of statistical significance was set at p-value less than 0.05.

Results

Sixty-two participants with unilateral above-knee amputations were recruited. Thirty-two patients were excluded (15 stump pain, five unhealed wound, seven previous stroke, and five coronary artery disease). Twenty amputees refused to participate (Figure 1). Two participants requested to quit the study during the third week of training due to transportation problems. Finally, eight participants took part in the study (Table 1). The mean age was 52.5±13.7 years old. Six participants were male, with an average height 164±5.3 cm, average weight 66.8±7.6 kg, and mean body mass index 24.6±2.37. Four participants underwent amputation more than five years prior to the study and two participants were amputated in a past year. All of them had worn their current prosthesis for more than three months. Most causes of amputations were trauma (62.5%), which included road accidents, blast injury, and gun shoot wounds. Most stump length were long stumps according to the International Society for Prosthetics and Orthotics (ISPO) criteria. All the participants had the same prosthetic components, including solid ankle cushioned heel (SACH) foot, endoskeletal shank, polycentric axis knee unit, and Silesian belt suspension. All participants were classified as K3.

There were significant improvements of mean peak torque of all hip muscle groups after training (Table 2). All participants showed no significant change in the median of temporo-spatial gait parameters. For the amputated limb, there was significant decreased of anterior-posterior pelvic tilt (Gyro Y axis) during the stance phase. For the intact limb, there was also significant decreased of anterior-posterior pelvic tilt during the swing phases (Table 3). The data of gait cycle showed asymmetry between the prosthetic and sound limb. There was a shortening of the stance phase in the prosthetic limb, with a statistically significant side by side difference. This finding did not change after exercise training.

Table 2. Comparison hip muscle strength between pre- and post-isokinetic training (n=8)

Muscle group	Pre-exercise peak torque (Nm) Mean±SD	Post-exercise peak torque (Nm) Mean±SD	Mean difference* (95% CI)	% change**	p-value
Hip extensor	45.92±19.51	59.36±19.78	13.43 (6.38 to 20.48)	38.04	0.002
Hip flexor	42.03±18.49	55.32±22.63	13.28 (2.59 to 23.98)	41.56	0.021
Hip adductor	36.60±13.38	48.54±13.03	11.94 (6.76 to 17.11)	37.20	<0.001
Hip abductor	33.44±10.77	47.01±11.26	13.57 (9.75 to 17.39)	44.56	<0.001

SD=standard deviation; CI=confidence interval

* Mean of peak torque difference between pre- and post-exercise training, ** Percent change of post-exercise peak torque compared with pre-exercise peak torque

Table 3. Comparison gait parameter during comfortable walking speed between pre- and post- isokinetic training (n=8)

Gait parameter	Prosthesis limb; mean			Sound limb; mean			p-value (prosthetic/sound limb)	
	Before	After	p-value	Before	After	p-value	Before	After
Spatiotemporal parameters								
Speed (m/s)	0.54	0.53	0.889	-	-	-	-	-
Cadence(step/minute)	66	64	0.866	-	-	-	-	-
Step length (m)	0.464	0.423	0.401	0.432	0.421	0.674	0.050	0.069
Step time (second)	0.774	0.731	0.945	0.880	0.923	0.640	0.017	0.025
Single support (%)	75	72	0.674	-	-	-	-	-
Double support (%)	25	28	0.674	-	-	-	-	-
Stance phase (%)	55	54	0.401	72	72	0.889	0.012	0.012
Swing phase (%)	45	46	0.401	28	28	0.889	0.012	0.012
Kinematic parameters								
Stance phase								
• Gyro X axis	7.989	8.293	0.636	8.195	9.276	0.829	-	-
• Gyro Y axis	6.226	3.181	0.017	−4.034	−3.130	0.263	-	-
• Gyro Z axis	5.640	5.121	0.172	−4.323	−2.515	0.995	-	-
Swing phase								
• Gyro X axis	14.605	15.386	0.179	−7.457	−8.212	0.771	-	-
• Gyro Y axis	11.819	6.334	0.208	−8.551	−3.259	0.012	-	-
• Gyro Z axis	8.314	7.413	0.250	−9.471	−7.562	0.913	-	-

m/s=meter per second; Gyro X=frontal plane; Gyro Y=sagittal plane; Gyro Z=transverse plane

Discussion

The present study results showed that a training program could significantly improve the hip muscle strength of the above-knee amputees. However, walking speed of the patients was not improved compared to normal adults, which was 0.53 meter per second compared to 1.22 meter per second. Although hip muscles strength is an important factor to increase walking ability[12], the authors found persistent slow gait speed in the study subjects despite positive results on hip muscles strength. As shown in a previous study by Ryser et al[13], the above knee amputees lose their hip extensor and hip flexor strength by 35% and 84% respectively, compared to healthy young adults. Hence, the 38% to 41% improvement in hip muscles strength in the present study program were still inadequate to improve the gait speed. Other influencing factors such as gait training program, psychological therapy, and duration of intervention may also be important to correct gait abnormality aside from hip muscles strength. Previous studies demonstrated a 50% improvement of gait speed with muscle strengthening program along with gait re-education and psychological training[7,14]. The treatment period, which was 10 weeks, was longer in the previous study to improve gait speed and muscle strength compared to the present study[6].

Systematic review about kinematics study of gait in above knee amputation showed a significant increase in anterior pelvic tilt of amputated limb as compared with intact limb and degree of tilting, which is more than twice as large as normal subjects[15,16]. The present study had found reduced pelvic motion (50%) in sagittal plane that reflected better pelvic control during gait after the isokinetic hip strengthening program. Unchanged pelvic motion in frontal and transverse plane as well as some motion for compensatory mechanism may be needed in the training to maintain the prosthesis leg and prevent further problems.

Asymmetry of gait in amputees was not changed post-treatment for both step time asymmetry and stance-swing phase ratio. This consistent abnormality could be caused by the prosthetic design. All participants used passive type prosthesis, which has a push off deficiency[17], resulting in anterior propulsion impairment. The authors found slow gait speed in the late stance and through swing phase. Moreover, step length symmetry in amputees has been shown to affect consequences in asymmetric trunk progression and forward foot placement relative to the trunk[18]. Further study for gait analysis in amputee with different types of foot should be applied, especially single axis or energy storage foot, which has some push off assist[19]. Another reason for the slow gait speed in the study participants could be because previous study found increased walking speed affected reduced temporal and loading asymmetry in above knee amputation[20].

The results from the present study could provide suggestion to improve the above-knee amputee training program. Program should include strengthening exercises, prosthetic training, and gait re-education. However, improvement of a prosthetic component to resolve the push off deficiency might be required to improve gait performance especially in highly active amputees.

The limitations of the present study were the lack of hip muscle strength measurement in the normal limb, so, the authors did not know exactly the normal strength value in each patient. Furthermore, gait analysis with Tailgait cannot provide information about truncal and lumbopelvic motion, which may be improved after training.

Conclusion

The present study provides evidence of the efficacy of a three-week isokinetic training of hip muscles with improved hip strength and better pelvic control but without any significant change in walking speed.

What is already known on this topic?

Hip muscle strengthening is recommended in most guideline for post above-knee amputation training because hip muscle strength thought is an important factor to improve gait. However, there is limited evidence to demonstrate the effect of hip strengthening exercise only on gait performance. Moreover, there was no standard set for strengthening exercise in above-knee amputee and most patient still have weak hip muscles.

What this study adds?

Doing Isokinetic exercise training for three weeks was effective to increase hip muscle strength in above knee amputees. This study showed better hip control after hip muscle strength was increased. However, gait performance needs an additional program that would be a specific gait training to be improved.

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Conflicts of interest

The authors declare no conflict of interest in all financial and instrumental support.

References

1. National Statistical Office of Thailand. Report of disabled person survey 2017 (Internet). Bangkok: National Statistical Office of Thailand; 2018 (cited 2018 May 19). Available from: http://statbbi.nso.go.th/staticreport/page/sector/th/06.aspx.
2. Kegel B, Webster JC, Burgess EM. Recreational activities of lower extremity amputees: a survey. Arch Phys Med Rehabil 1980;61:258-64.
3. Raetai P, Pusiripinyo E, Wattanapan P. Comparative gait analysis on level surfaced path of normal subjects and amputees using KKU 2 knee joint prosthesis. J Thai Rehabil Med 2013;23:24-8.
4. Sansam K, Neumann V, O'Connor R, Bhakta B. Predicting walking ability following lower limb amputation: a systematic review of the literature. J

Rehabil Med 2009;41:593-603.
5. Croisier JL, Maertens de Noordhout B, Maquet D, Camus G, Hac S, Feron F, et al. Isokinetic evaluation of hip strength muscle groups in unilateral lower limb amputees. Isokinet Exerc Sci 2001;9:163-9.
6. Nolan L. A training programme to improve hip strength in persons with lower limb amputation. J Rehabil Med 2012;44:241-8.
7. Sjödahl C, Jarnlo GB, Persson BM. Gait improvement in unilateral transfemoral amputees by a combined psychological and physiotherapeutic treatment. J Rehabil Med 2001;33:114-8.
8. Wong CK, Ehrlich JE, Ersing JC, Maroldi NJ, Stevenson CE, Varca MJ. Exercise programs to improve gait performance in people with lower limb amputation: A systematic review. Prosthet Orthot Int 2016;40:8-17.
9. Manit J, Youngkong P. TailGait: A light-weight wearable gait analysis system. In: Seventh International Conference on Sensing Technology (ICST); 3-5 Dec 2013; Wellington; 2013. p. 540-4.
10. Kannus P. Isokinetic evaluation of muscular performance: implications for muscle testing and rehabilitation. Int J Sports Med 1994;15 Suppl 1:S11-S18.
11. Wimpenny P. Hip internal/external rotation. Isokinetics explained (Internet). 2016 (cited 2019 Jun 15). Available from: https://www.isokinetics.net/index.php/practicle/hip.
12. Visser J, McCarthy I, Marks L, Davis RC. Is hip muscle strength the key to walking as a bilateral amputee, whatever the level of the amputations? Prosthet Orthot Int 2011;35:451-8.
13. Ryser DK, Erickson RP, Cahalan T. Isometric and isokinetic hip abductor strength in persons with above-knee amputations. Arch Phys Med Rehabil 1988;69:840-5.
14. Sjödahl C, Jarnlo GB, Soderberg B, Persson BM. Kinematic and kinetic gait analysis in the sagittal plane of trans-femoral amputees before and after special gait re-education. Prosthet Orthot Int 2002;26:101-12.
15. Devan H, Carman A, Hendrick P, Hale L, Ribeiro DC. Spinal, pelvic, and hip movement asymmetries in people with lower-limb amputation: Systematic review. J Rehabil Res Dev 2015;52:1-19.
16. Sjödahl C, Jarnlo GB, Soderberg B, Persson BM. Pelvic motion in trans-femoral amputees in the frontal and transverse plane before and after special gait re-education. Prosthet Orthot Int 2003;27:227-37.
17. Adamczyk PG, Kuo AD. Mechanisms of Gait Asymmetry Due to Push-Off Deficiency in Unilateral Amputees. IEEE Trans Neural Syst Rehabil Eng 2015;23:776-85.
18. Roerdink M, Roeles S, van der Pas SC, Bosboom O, Beek PJ. Evaluating asymmetry in prosthetic gait with step-length asymmetry alone is flawed. Gait Posture 2012;35:446-51.
19. van der Linden ML, Solomonidis SE, Spence WD, Li N, Paul JP. A methodology for studying the effects of various types of prosthetic feet on the biomechanics of trans-femoral amputee gait. J Biomech 1999;32:877-89.
20. Nolan L, Wit A, Dudzinski K, Lees A, Lake M, Wychowanski M. Adjustments in gait symmetry with walking speed in trans-femoral and trans-tibial amputees. Gait Posture 2003;17:142-51.