

Muscle torque of the hip joint flexors and extensors in physically active and inactive amputees

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Summary

Study aim: The aim of this study was to assess proportion and symmetry between torque in muscles that affect the hip joint in the non-amputated and the amputated limb in persons both engaged in and not engaged in sports.

Material and methods: Study participants comprised 12 persons with above-knee leg amputation. The group of participants was divided into two subgroups: persons engaged in sports and physically inactive persons.

The strength and the speed capacity of hip joint flexors and hip joint extensors were measured using a Biodex System 4 dynamometer. The measurement was conducted at two angular velocities (60°/s and 120°/s) and during isometric activity of the non-amputated and the amputated limb.

Results: Maximal torque of hip joint flexors in the amputated limb of physically active persons constituted 65.3% of the corresponding value in persons without amputation and was higher than in physically inactive persons (55.9%). Similar values were obtained for extensors. The time to reach maximal muscle torque in the amputated limb during the extension of the hip joint at 60°/s equalled 400 ms in physically active persons and 900 ms in physically inactive persons and during flexion, equalled 400 ms and 600 ms, respectively.

Conclusions: Physically active persons showed greater dynamics in generating maximal muscle torque, especially during the extension of the hip joint. Physical activity benefits the strength and speed capacity of muscles that affect the hip joint in persons with above-knee amputation, thus decreasing asymmetry and disproportion between limbs.

Keywords: Physical activity – Muscle torque – Symmetry – Amputation

Introduction

Unilateral above-knee amputation causes muscles that affect the hip joint to lose strength and muscle mass in the hip to decrease [4, 11, 14]. Differences between hip joint flexors and extensors and between the non-amputated limb and the amputated limb amount to 40–60% [8, 14]. Amputation affects the state and functioning of muscles primarily through muscle atrophy and decreases in the rate of muscle flexion on the amputated side [2, 14, 16, 22]. Persons with amputation can avoid these effects by participating in an appropriate rehabilitation program or through engagement in disability sports [7, 19].

Hip joint muscles in persons with unilateral amputation undergo considerable strain that causes significant asymmetry in the parameters of walking and running [5, 15]. Research has indicated that above-knee amputation results in

changes to the structure of leg muscle stimulation [8, 18]. Differences between limbs in muscle strength capacity may also lead to strain and quicken degenerative changes [10]. The negative effects of amputation can be eliminated through physiotherapy and physical activity. Studies conducted among persons with above-knee amputation indicate that physical activity improves the strength and speed capacity of the amputated limb [18]. It can therefore be assumed that physical activity in the form of engagement in disability sports may also improve proportions and symmetry between leg muscles in persons with above-knee amputation.

The aim of this study was to assess proportions and symmetry between muscle torque in hip joint flexors and extensors in the non-amputated and amputated limb in physically active and physically inactive persons. Determining differences between physically active and physically inactive persons and the level of deficit in physically inactive persons could aid persons who work in the field

of disability sports or who conduct competitive sports therapy by allowing them to compare the results of this study to their own results.

Material and methods

Study participants comprised a group of 12 persons (10 men and 2 women) with above-knee amputation. Six persons lost their leg due to injury, four due to cancer, and two due to congenital disorders. Seven persons lost their left leg, and five persons lost their right leg. All participants had a prosthesis, and none used forearm crutches. The group of participants was divided into two subgroups. The first subgroup (mean age 38 ± 15 years, body mass 72 ± 20 kg, body height 172 ± 80 cm) included persons who undertook sports at least two times a week (swimming, sitting volleyball, or wheelchair tennis). The second subgroup (mean age 44 ± 17 years, body mass 82 ± 18 kg, body height 178 ± 11 cm) included physically inactive persons. Normative data were obtained from available data for the same groups of muscles affecting the hip joint in persons without amputation at the same age as the study participants [13]. Participants did not report any health problems on the day of the assessment. Persons who underwent hip replacement or who had lower spine pain, neurological loss of muscle strength, or diseases that directly affected the movement system were excluded from the study. Persons with a hip stump length of at least 22 cm, as measured from the greater trochanter, were qualified for participation in the study. Prior to the measurement, the participants were instructed about the aim of the study and the measurement methodology. The participants signed an agreement to participate in the study. At any stage of the assessment, participants were able to refuse to undergo measurements without having to indicate the reason. The Bioethics Committee at the Wrocław Medical University positively reviewed the project.

Assessments of strength and speed capacity of the hip joint flexors and extensors were conducted using a Biodex

System 4 dynamometer [21]. Prior to assessment, participants removed their orthopaedic aids. The skin of each participant's stump was examined, and the band of the dynamometer was attached. The device allowed the movement axis of the dynamometer to be precisely adjusted to the movement axis in the hip joint. The position of the participant and angular velocity were adjusted according to the recommendations of the manufacturer of the dynamometer. The trunk of the participant was stabilised using two belts, with an additional belt used to stabilise the pelvis. Prior to assessment, each participant was familiarised with the type of movement to be performed and the resistance involved. Both limbs were measured in the sagittal plane at two angular velocities ($60^\circ/\text{s}$ and $120^\circ/\text{s}$) and in isometric conditions with the hip joint flexed at an angle of 90° . Five measurements were taken for each of the three measurement conditions. A break of at least one minute was taken between isokinetic measurements and a break of thirty seconds was taken between isometric measurements. Measurement of rotation, abduction, and adduction in the hip joint was impossible due to the lack of the knee joint in one of the limbs.

The Mann-Whitney U test for small sample sizes (below 20) was used to assess differences in mean values between physically active and physically inactive persons. The following parameters were calculated: relative and absolute muscle torque and the time to reach maximal muscle torque. Furthermore, the proportion of muscle torque between hip joint flexors and hip joint extensors was determined.

Results

Hip joint flexors

The non-amputated limb displayed higher muscle torque values of hip joint flexors than the amputated limb in both groups (Table 1). Physically active persons obtained higher muscle torque values of the flexors for both

Table 1. Relative muscle torque and time to peak torque of hip joint flexors among physically active and inactive persons for the non-amputated (N-a) and the amputated (A) limb

	Hip joint flexors					
	Isometric		$60^\circ/\text{s}$		$120^\circ/\text{s}$	
	Active	Inactive	Active	Inactive	Active	Inactive
Relative torque [Nm/kg]						
N-a limb	1.32 ± 0.292	1.02 ± 0.531	1.58 ± 0.404	1.32 ± 0.512	1.32 ± 0.363	1.16 ± 0.401
A limb	0.96 ± 0.192	0.84 ± 0.288	1.08 ± 0.439	0.94 ± 0.253	0.91 ± 0.363	0.77 ± 0.304
Time to peak torque [ms]						
N-a limb	–	–	572.0 ± 261.9	705.0 ± 332.3	500.0 ± 421.3	410.0 ± 260.5
A limb	–	–	380.0 ± 71.2	638.0 ± 368.6	235.0 ± 87.0	393.0 ± 245.4

limbs than physically inactive persons did. However, the differences were not statistically significant. Interestingly, higher values were obtained during isokinetic activity than during isometric activity. Muscles of the amputated limb reached maximal muscle torque faster among physically active persons than among physically inactive persons. In both groups, the non-amputated limb showed a longer time of generating maximal muscle torque than the amputated limb.

Because study participants varied greatly in terms of age (20–70 years old), the results obtained by each participant were compared to those taken from literature concerning persons without amputation (Figure 1). The comparison was made only for the 60°/s velocity. This velocity was chosen in view of normative data collected by Harbo for hip joint flexors in persons without amputation [13].

Regardless of the level of physical activity, persons with amputation did not achieve the norm for persons without amputation. The mean value of maximal absolute muscle torque of hip joint flexors in the amputated limb among physically active persons constituted 65.3% of the value for persons without amputation and was higher than among physically inactive persons with amputation (55.9%).

Hip joint extensors

Even though the amputated limb achieved lower values among physically inactive persons than among physically active persons, the non-amputated limb displayed an opposite tendency during isometric measurements (Table 2). The differences were not statistically significant. Physically active persons achieved a shorter time for reaching maximal muscle torque in the amputated limb during the

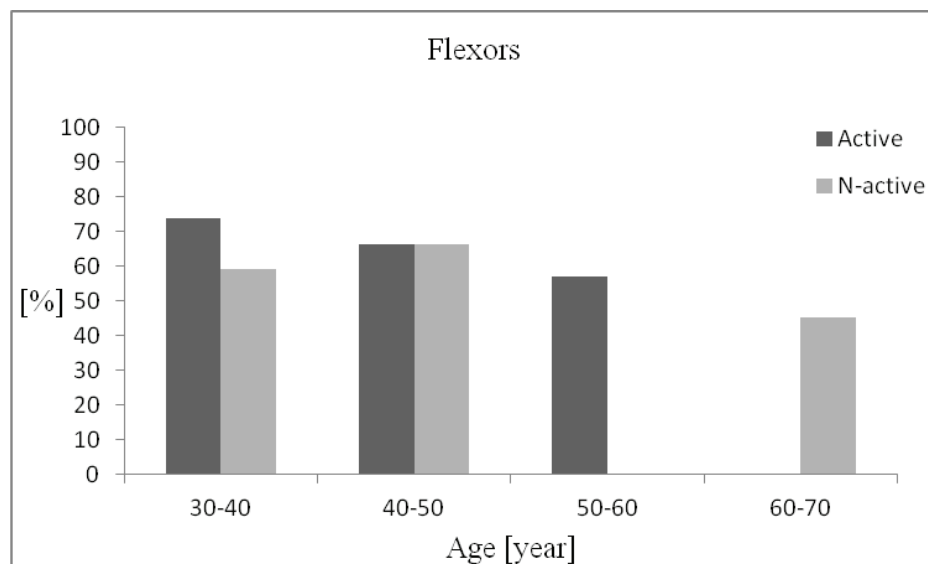


Fig. 1. Maximal muscle torque of hip joint flexors compared to values obtained by persons without amputation at the same age as the study participants

Table 2. Relative torque and time of reaching the maximal muscle torque of the hip joint extensors among physically active and inactive persons for the non-amputated (N-a) and the amputated (A) limb

	Hip joint extensors					
	Isometric		60 °/s		120 °/s	
	Active	Inactive	Active	Inactive	Active	Inactive
Relative torque [Nm/kg]						
N-a limb	1.39 ± 0.419	2.06 ± 1.443	1.83 ± 0.479	1.57 ± 0.658	1.29 ± 0.467	1.19 ± 0.632
A limb	1.17 ± 0.620	1.12 ± 0.725	1.40 ± 0.745	1.08 ± 0.457	1.16 ± 0.603	0.88 ± 0.446
Time to peak torque [ms]						
N-a limb	–	–	457.0 ± 130.3	497.0 ± 329.8*	277.0 ± 143.9	468.0 ± 204.3*
A limb	–	–	390.0 ± 129.1	880.0 ± 436.0*	305.0 ± 81.0	513.0 ± 235.4*

* – statistically significant differences at $p < 0.02$

extension of the hip joint at the velocity of 60°/s and in the non-amputated limb during extension at the velocity of 120°/s. These differences were statistically significant at $p < 0.02$.

Figure 2 shows values of maximal absolute muscle torque of hip joint extensors compared to persons without amputation. As with the hip joint flexors, muscle torque values for the hip joint extensors in persons without amputation at the same age as the study participants were taken from Harbo's research [13]. The mean maximal absolute muscle torque of the hip joint extensors in the amputated limb amounted to 60.5% among physically active persons and to 50.8% among physically inactive persons. As with the hip joint flexors, physically active persons displayed a higher mean maximal absolute muscle torque.

the amputated limb for the hip joint flexors measured in isometric conditions was higher among physically active persons than among physically inactive persons. The hip joint extensors displayed an opposite tendency.

Discussion

Physical activity of healthy persons is a popular subject among researchers [3, 17]. The World Health Organisation has established norms for healthy persons concerning the amount of recommended physical activity that should be taken up to maintain health [20]. Unfortunately, studies rarely address the problem of sedentary lifestyle among persons with disabilities, even though the consequences of

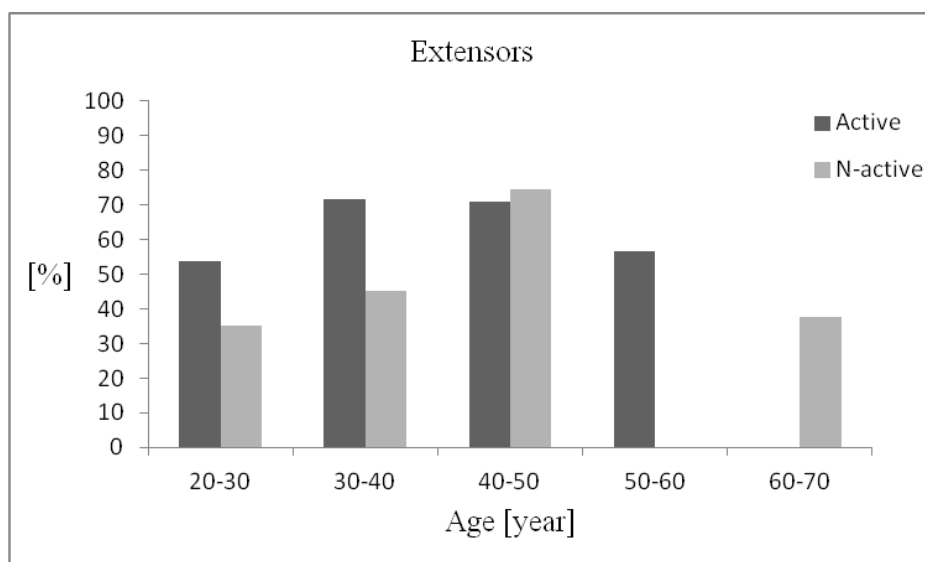


Fig. 2. Maximal muscle torque of hip joint extensors compared to values obtained by persons without amputation at the same age as the study participants

Symmetry and proportion between muscle torque of hip joint flexors and extensors

Calculations of the symmetry between the non-amputated and the amputated limb and of the proportions between the hip joint flexors and extensors were performed in order to assess the potential strain of the movement system in persons with amputation (Table 3). The mean difference in the symmetry between the non-amputated and

such a lifestyle are the same as for persons without disabilities. Studies indicate that persons with amputation are much less physically active than persons without amputation are [12]. This may be caused by the increased energy cost of walking, a change in lifestyle compared to the period before the amputation, and comorbidity. Research indicates that persons who undergo amputation for reasons other than a cardiovascular disorder display greater

Table 3. Mean percent decrease (deficit) in the maximal muscle torque of the non-amputated limb compared to the amputated limb

	Isometric [%]		60 °/s [%]		120 °/s [%]	
	A	N-a	A	N-a	A	N-a
Flexion	25.0	9.5	39.4	23.4	38.7	32.0
Extension	15.1	39.9	32.7	28.2	23.1	25.6

physical activity [24]. Increased physical activity among persons with disabilities allows them to achieve fuller independence in everyday life [9] and to participate in disability sports.

As expected, physically active persons showed superior strength capacity of muscles affecting the hip joint in comparison to physically inactive persons. However, these differences were statistically insignificant. This study found lower values of muscle torque on the amputated side, as have studies by other authors. These values indicate muscle atrophy in the stump of the hip [2, 4, 8, 14, 23].

Conducting research that addresses persons with amputation proves problematic. It is difficult to create a group of persons of the same age, which is why the results of our measurements were compared to persons without amputation at a similar age to the persons with amputation. Physically active as well as physically inactive persons with amputation showed lower absolute values of muscle torque than their peers without amputation [6]. The hip joint flexors were stronger than the hip joint extensors in persons with amputation regardless of the level of physical activity. Nolan [18] obtained similar results among persons with below-knee amputation. Croisier [8] also noticed that hip joint extensors displayed a 33% decrease in maximal torque. The superior strength capacity of the hip joint extensors may be explained by the fact that these muscles function as antigravity muscles. Both groups of study participants used prostheses in their daily lives, which meant that their hip joint extensors had to compensate for the muscles of the knee and ankle joints lost as a result of amputation [15, 22]. However, physically active study participants showed a lower percentage decrease in muscle torque than physically inactive study participants in comparison to persons without amputation in terms of both flexion and extension of the hip joint. This may indicate a beneficial effect of physical activity on the movement system of physically active study participants.

Another parameter assessed in this study was the time to reach maximal muscle torque, which indicated the structure of leg muscle stimulation. The shorter time of reaching maximal muscle torque achieved by physically active persons compared to physically inactive persons indicates a beneficial effect of physical activity on the dynamics of muscle torque generation, especially during extension. Burger [4] confirms the importance of this parameter in assessing muscle strength capacity in persons with amputation. In his study that assessed the effect of the activity of the gluteus maximus muscle, Burger observed that in addition to the atrophy of the muscle in question, amputation leads to lowered dynamics of generating maximal muscle torque as a result of slower contraction.

Asymmetry in strength capacity between the amputated and non-amputated limb may indicate potential damage

to the motor system [22]. Major disproportions between limbs may force a person to eliminate the difference through compensation. Unexpectedly, physically active persons showed considerable differences in the symmetry of muscle torque compared to physically inactive persons, especially for the hip joint flexors. However, the level of asymmetry between the non-amputated and the amputated limb among physically active as well as physically inactive persons indicates a need for these persons to undergo rehabilitation in order to reduce the disproportions. It should be emphasised that the results obtained by the study participants may have been affected by such factors as fear of maximal engagement in the tests, the specifics of a given sports discipline, and the level of muscle strength and physical activity before the amputation. Conducting research involving the assessment of strength and speed parameters of muscles that affect the hip joint in persons with amputation is extremely important, as physical activity may contribute to the improvement of the dynamic stability of the hip joint on both the amputated and the non-amputated sides.

Conclusions

1. Persons engaged in sports showed higher dynamics of generating maximal muscle torque, especially during the extension of the hip joint, which indicates that physical activity has a beneficial effect on the rate at which locomotor units are mobilised.
2. Physical activity improves the strength and speed capacity of muscles that affect the hip joint in persons with amputation by reducing asymmetry and disproportions between limbs.

References

1. Alexander M.J.L. (1990) Peak torque values for antagonist muscle groups and concentric and eccentric contraction types for elite sprinters. *Arch. Phys. Med. Rehabil.*, 71(5): 334-339.
2. Backlund L., Lemperg R., Ottosson L.G. (1968) Leg muscle strength in below-knee amputees. *Acta Orthop. Scand.*, 39(1): 107-116, DOI: 10.3109/17453676808989445
3. Bergmann G., Deuretzbacher G., Heller M., Graichen F., Rohlmann A., Strauss J., Duda G.N. (2001) Hip contact forces and gait patterns from routine activities. *J. Biomech.*, 34(7): 859-871, DOI: 10.1016/S0021-9290-(01)00040-9
4. Burger H., Valencic V., Marincek C., Kogovsek N. (1996) Properties of musculus gluteus maximus in above-knee amputees. *Clinic. Biomech.*, 11(1): 35-38, DOI: 10.1016/0268-0033(95)00032-1

5. Burkett B., Smeathers J., Barker T. (2003) Walking and running inter-limb asymmetry for paralympic trans-femoral amputees, a biomechanical analysis. *Prosthet. Orthot. Int.*, 27(1): 36-47.
6. Calmels P.M., Nellen M., van der Borne I., Jourdin P., Minaire P. (1997) Concentric and eccentric isokinetic assessment of flexor-extensor torque ratios at the hip, knee, and ankle in a sample population of healthy subjects. *Arch. Phys. Med. Rehabil.*, 78(11): 1224-1230, DOI: 10.1016/s0003-9993(97)90336-1
7. Crenshaw J.R., Kaufman K.R., Grabiner M.D. (2013) Compensatory-step training of healthy, mobile people with unilateral, transfemoral or knee disarticulation amputations: A potential intervention for trip-related falls. *Gait and Posture*, 38(3): 500-506, DOI: 10.1016/j.gaitpost.2013.01.023
8. Croisier J.L., de Noordhout B.M., Maquet D., Camus G., Hac S., Feron F., Crielaard J.M. (2001) Isokinetic evaluation of hip strength muscle groups in unilateral lower limb amputees. *Isokinet. Exerc. Sci.*, 9(4): 163-169.
9. Doukas W.C., Hayda R.A., Frisch H.M., Andersen R.C., Mazurek M.T., Ficke J.R., MacKenzie E.J. (2013) The Military Extremity Trauma Amputation/Limb Salvage (METALS) Study Outcomes of Amputation Versus Limb Salvage Following Major Lower-Extremity Trauma. *J. Bone Joint Surger. Am. Vol.*, 95A(2): 138-145, DOI: 10.2106/jbjs.k.00734
10. Gailey R., Allen K., Castles J., Kucharik J., Roeder M. (2008) Review of secondary physical conditions associated with lower-limb amputation and long-term prosthesis use. *J. Rehabil. Res. Dev.*, 45(1), DOI: 10.1682/jrrd.2006.11.0147
11. Gottschalk F.A., Stills M. (1994) The biomechanics of trans-femoral amputation. *Prosthet. Orthot. Int.*, 18(1): 12-7.
12. Halsne E.G., Waddingham M.G., Hafner B.J. (2013) Long-term activity in and among persons with transfemoral amputation. *J. Rehabil. Res. Dev.*, 50(4): 515-529, DOI: 10.1682/jrrd.2012.04.0066
13. Harbo T., Brincks J., Andersen H. (2012) Maximal isokinetic and isometric muscle strength of major muscle groups related to age, body mass, height, and sex in 178 healthy subjects. *Euro. J. Appl. Physiol.*, 112(1): 267-275, DOI: 10.1007/s00421-011-1975-3
14. Jaegers S., Arendzen J.H., Dejongh H.J. (1995) Changes in hip muscles after above-knee amputation. *Clin. Orthop. Relat. Res.*, (319), 276-284.
15. Liu M.Q., Anderson F.C., Schwartz M.H., Delp S.L. (2008) Muscle contributions to support and progression over a range of walking speeds. *J. Biomech.*, 41(15): 3243-3252, DOI: 10.1016/j.jbiomech.2008.07.031
16. Moirenfeld I., Ayalon M., Ben-Sira, D., Isakov E. (2000) Isokinetic strength and endurance of the knee extensors and flexors in trans-tibial amputees. *Prosthet. Orthot. Int.*, 24(3): 221-225, DOI: 10.1080/03093640008726551
17. Mynarski W.N.A., Rozpara M., Garbaciak W. (2012) Physical activity of male and female adolescents living in a town and a city in the context of public health recommendations. *Biomed. Hum. Kinetics*, 4: 18-23. DOI:10.2478/v10101-012-0004-2
18. Nolan L. (2009) Lower limb strength in sports-active transtibial amputees. *Prosthet. Orthot. Int.*, 33(3): 230-241, DOI: 10.1080/03093640903082118
19. Nolan, L. (2012) A training programme to improve hip strength in persons with lower limb amputation. *J. Rehabil. Med.*, 44(3): 241-248, DOI: 10.2340/16501977-0921
20. Pastuszek A.L.K., Lewandowska J., Buśko K. (2014) Level of physical activity of physical education students according to criteria of the IPAQ questionnaire and the recommendation of WHO experts. *Biomed. Hum. Kinetics*, 6: 5-11, DOI:10.2478/bhk-2014-0002
21. Pontaga I. (2004). Hip and knee flexors and extensors balance in dependence on the velocity of movements. *Biol. Sport*, 21(3): 261-272.
22. Ryser D.K., Erickson, R.P., Cahalan T. (1988) Isometric and isokinetic hip abductor strength in persons with above-knee amputation. *Arch. Phys. Med. Rehabil.*, 69(10): 840-845.
23. Seroussi R.E., Gitter A., Czerniecki J.M., Weaver K. (1996) Mechanical work adaptations of above-knee amputee ambulation. *Arch. Phys. Med. Rehabil.*, 77(11), DOI: 10.1016/s0003-9993(96)90151-3
24. Wezenberg D., van der Woude L.H., Faber W.X., de Haan A., Houdijk H. (2013) Relation Between Aerobic Capacity and Walking Ability in Older Adults With a Lower-Limb Amputation. *Arch. Phys. Med. Rehabil.*, 94(9): 1714-1720, DOI: 10.1016/j.apmr.2013.02.016

Received 05.05.2014

Accepted 17.07.2014

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