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Stump length as related to atrophy and strength of the thigh muscles in trans-tibial amputees

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Abstract

Stump length and the thigh muscles strength of the amputated limb are among the major factors influencing outcome of prosthetic rehabilitation of trans-tibial amputees. In the present study the authors evaluated and compared the strength of quadriceps and hamstrings muscles of both limbs in trans-tibial amputees, as measured by means of an electrical dynamometer. The obtained results showed that the thigh muscles of the sound limbs are significantly stronger than those of the amputated limbs ($p<0.01$). The results obtained for amputees with shorter stumps were compared to those with longer stumps. In the group of amputees ($n=9$) with a stump shorter than 15.1 cm, values of peak torque (in isokinetic contraction) and maximal average torque (in isometric contraction) were significantly ($p<0.5$) weaker when compared to those ($n=9$) with a stump longer than 15.1 cm. The results obtained for amputees with a higher rate of thigh muscle atrophy were compared to those with lesser atrophy. In the group of amputees where muscle atrophy was accompanied by decrease in thigh girth of over 5.9 cm, muscles strength did not significantly decrease ($p<0.5$) as compared to amputees where thigh girth decrease was less than 5.9 cm. It is concluded that atrophy of the thigh muscles of trans-tibial amputees is accompanied with a significant decrease in strength. In amputees with a short stump, the short lever action provided by the stump interferes with the ability of the thigh muscles to control the prosthesis efficiently during daily activities such as standing and walking.

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Introduction

A short stump might interfere with success in prosthetic rehabilitation of trans-tibial amputees. An adequately long stump provides the amputee with a good proprioceptive feedback (Guerts and Mulder, 1992) resulting from both a large contact surface and good stability of the stump-socket unit. These factors enable good standing and walking in these patients (Isakov *et al.*, 1985; Isakov *et al.*, 1994; Seliktar *et al.*, 1980). When the stump of a trans-tibial amputee is short and the transverse and longitudinal dimensions are almost similar, the stump acquires a round shape and may become unstable inside the prosthetic socket (Seliktar *et al.*, 1980; Nissan, 1977). As a result, instability of the stump-prosthesis complex creates shear forces with resulting pain and/or blisters or friction sores which prevent prosthesis usage for a long period of time. Researchers have studied the forces acting on a short trans-tibial stump (Sanders *et al.*, 1992; Lilja *et al.*, 1993) and various prosthetic solutions have been suggested for improving stability of the stump-socket unit and the quality of standing and walking (Isakov *et al.*, 1992; Pritham, 1979).

It is suggested that the stump of trans-tibial amputees is less active in the daily functions of standing and walking. In fact, atrophy of the thigh muscles of the amputated limb is often observed among such amputees, a finding evident from quadriceps muscle biopsies (Renstrom *et al.*, 1983). Evaluation of standing balance activity of both limbs in trans-tibial amputees showed that the foot-ground reactive forces generated by the amputated limb are

Table 1. Variables of trans-tibial amputees subjects (TT: tibial tuberosity, PTS: patellar tendon supracondylar, PTB: patellar tendon bearing)

n=18			
Sex	(F/M)	6/12	
Age	(yr)	45.7±14.7	(27-74)
Amputation			
- side	(R/L)	6/12	
- duration	(yr)	13.4±14.4	(1-46)
Stump			
- length	(cm)	15.1±3.2	(8.5-21)
- thighs girth diff.:	(cm)		
	- 18 cm above TT	5.9±2.5	(2-12.5)
	- 30 cm above TT	4.0±2.9	(0-10.5)
Walking			
- distance	(km)	2.5±1.4	(0.5-10)
- prosthesis			
	PTS	4	
	PTB+belt	12	
	PTB+corset	2	
- aids	none	17	
	cane/crutch	3	

smaller (Isakov *et al.*, 1992; Geurts and Mulder, 1992). Analysis of gait in trans-tibial amputees showed a shorter body weight bearing stance phase on the amputated limb as well as asymmetry in other gait phases (Baker and Hewison, 1990). It can therefore be assumed that reduced involvement and activation of the amputated limb muscles in activities such as standing and walking results in disuse atrophy of the thigh muscles of the affected limb. The present study aimed at evaluating whether the stump length and thigh muscles atrophy are related to the strength of the thigh muscles in trans-tibial amputees.

Subjects

Eighteen volunteers, 6 female and 12 male, with trans-tibial amputation were assessed (Table 1). Their average age was 45.7±14.7 years (range, 27 to 74 years). The mean time from the amputation to the present study was 13.4±14.4 years (range, 1 to 46 years). Causes for amputation were; traffic injury 6, work accident 5, war injury 1, diabetes mellitus 2, peripheral arterial disease 1, tumour 1, infection 2.

Subjects' mean stump length was 15.1±3.2 cm (range, 8.5 to 21 cm). The thigh girth at 18 cm above the tibial tuberosity of the amputated limb was smaller compared with the contralateral limb (5.9±2.5; range: 2-12.5 cm). At 30 cm above the tibial tuberosity the difference was 4.0±2.9 cm (range: 0-10.5 cm). All subjects were fitted with a patellar tendon-bearing prosthesis. They were using their prostheses for the whole day and were able to walk continuously a mean distance of 2.5±1.4 km. No subject had any knee joint contracture or complaints of knee or stump pain during the test.

Methods

Measurements

In each subject, measurements of the thigh girth were taken at an equal distance from the tibial tuberosities of both legs, proximally 18 and 30 cm. Measurements were taken by one of the team members using a standard tape measure, a method found reliable for measuring circumference of the lower limb (Renstrom *et al.*, 1983). Measurements were performed in the lying position with knees extended and thigh muscles relaxed.

Stump length was measured while the knee was in 90 degrees of flexion. The upper reference point was the medial femoro-tibial inter-condylar line and the lower point the stump tip.

Instrumentation

The isokinetic concentric and eccentric and isometric muscle torques of the knee extensors and flexors were measured on-line with Biodex Model B-2000 (Biodex, NY, USA) (Wilk and Johnson, 1988; Thompson *et al.*, 1993). A special lever was constructed to meet with the special needs of the tested stump. For each subject the lever arm was adjusted to rest at the same distance from the lower pole of the patella in both limbs. In order to eliminate the effect of gravity, the torque due to the mass of the limb was determined and then added to measured torque values when working against gravity and subtracted from the torque values when working with gravity. The dynamometer was calibrated according to the manufacturer's recommendations once a week.

Measured parameters: Muscular efficiency was evaluated by measuring the quadriceps and hamstrings isokinetic concentric and eccentric and isometric strength. Peak torque (Nm) is the highest value of torque developed throughout the range of motion curve. Maximal average torque (Nm) is the greatest average torque produced for a repetition within a set.

Procedure

Positioning: The patients were seated with hip joints angle of 90-100 degrees. Stabilisation straps were placed across the trunk, around the waist, and mid-thigh of the limb to be tested. The anatomical axis of the knee joint was visually aligned with the axis of rotation of the dynamometer.

Learning phase: Prior to each test, subjects were instructed and allowed to try the dynamometer. The differences between concentric, eccentric and isometric were explained. The subjects then performed submaximal contractions in order to be acquainted with the exercise.

Test sequence: The test procedure consisted of five consecutive isokinetic concentric contractions for the quadriceps and hamstrings muscle groups, followed by five eccentric contractions with five minutes rest. The constant angular velocity was established at 60 degrees per second. Following 5 minutes rest, each subject performed five consecutive isometric contractions of 5 seconds each. The quadriceps contraction was evalued at 45 degrees of flexion and the hamstrings contraction at 60 degrees of flexion. Subjects were asked to perform their maximal effort and verbal encouragement was provided to each subject throughout the test session. Statistical analysis of the significance of the results was performed using the paired t-test and the level of significance was set at $p<0.05$.

Results

The means and standard deviations of values (Nm) obtained for the quadriceps and hamstrings of both limbs are detailed in Table 2. Results relate to the three different strength measurements during isokinetic concentric, isokinetic eccentric (peak torque) and isometric contractions (maximal average torque). Values obtained in the muscles of the amputated limb were significantly smaller compared with the sound limb muscles ($p<0.01$). The test subjects were divided into two groups. The first group of nine amputees included those with stump length less than 15.1 cm, the second group of nine amputees had a stump length of more than 15.1 cm. Values of torques obtained in these two groups are detailed in Table 3. In the group with the shorter stump, quadriceps (eccentric contraction) and hamstrings (concentric contraction) strength was significantly smaller when compared to the group with a longer stump ($p<0.05$). All other values in the group

Table 2. Means and standard deviations (Nm) of muscles peak torque (isokinetic contraction) and maximal average torque (isometric contraction)

Muscle	Type of muscle contraction	Amputated limb	Sound limb	p
Quadriceps	Isokinetic concentric	40.4±20.5	76.7±31.0	.001
	Isokinetic eccentric	112.0±47.2	171.2±45.4	.002
	Isometric	46.0±26.4	93.0±34.0	.001
Hamstrings	Isokinetic concentric	29.9±20.0	74.6±34.8	.001
	Isokinetic eccentric	64.5±37.3	128.2±45.1	.001
	Isometric	30.3±20.4	52.6±24.3	.007

Table 3. Values of muscles peak torque (isokinetic contraction) and maximal average torque (isometric contraction). Means and standard deviations (Nm) are related to stump length

Muscle	Type of muscle contraction	Stump length: <15.1 cm (n=9)	<15.1 cm (n=9)	p
Quadriceps	Isokinetic concentric	32.6±16.6	48.3±21.9	.113
	Isokinetic eccentric	87.0±27.6	137.1±50.6	.016
	Isometric	35.4±17.3	60.4±31.7	.112
Hamstrings	Isokinetic concentric	19.1±6.0	40.6±23.6	.038
	Isokinetic eccentric	47.8±10.5	81.3±47	.075
	Isometric	22.1±12.6	38.3±24.2	.087

with the shorter stump were also smaller however less significantly (p<0.3).

Atrophy of the amputated thigh muscles as related to thigh girth differences were considered also. The subjects were divided into two groups according to girth differences obtained 18 cm above the tibial tuberosity. In the first group of nine amputees, thigh girth mean differences were greater than 5.9 cm and in the second group thigh girth mean differences were less than 5.9 cm. The mean of muscle torque in both groups were calculated and compared (Table 4) showing the differences in muscles strength between these groups to be insignificant (p<0.5).

Discussion

Although amputation surgery is a constantly improving process, there are still cases where it is not possible to construct a sufficiently long trans-tibial stump. In the present study, the amputees' average length of the stump was 15.1 cm (range: 8.5-21 cm) while others report an average length of 16 cm with a range between 10 and 25 cm (Persson and Liedberg, 1983). Stump length is the major factor determining stability of the BK stump inside the prosthetic socket and consequently the quality of standing and walking (Seliktar *et al.*, 1980; Nissan, 1977; Isakov *et al.*, 1992). Other important factors which influence the rehabilitation outcome of amputees are an optimal prosthesis fitting and strength of the quadriceps and hamstrings muscles controlling the knee of the affected limb (Klingenstierna *et al.*, 1990).

The authors evaluated the isokinetic and isometric strength of the amputated limb thigh muscles by means of a dynamometer. The advantages of this method when compared to manual muscle testing (Nicholas *et al.*, 1978; Iddlings *et al.*, 1961) are that it provides an objectively reproducible and reliable test (Steiner *et al.*, 1993; Wilke and Johnson, 1988; Thompson *et al.*, 1993). The obtained results for peak torque in isokinetic concentric and eccentric and for maximal average torque in isometric contraction were significantly smaller in the amputated limbs when compared to the sound limbs. The strength of thigh muscles of amputees with a short stump was compared with those with a longer stump. The obtained results indicate clearly a decrease in strength of the amputated limb thigh muscles in trans-tibial amputees with a short stump as evaluated under the described conditions. It is therefore assumed that the inefficient lever action provided by the

Table 4. Values of muscles peak torque (isokinetic contraction) and maximal average torque (isometric contraction). Means and standard deviations (Nm) are related to thigh girth. All comparisons are insignificant (p>.5)

Muscle	Type of muscle contraction	Thighs girth differences: <5.9 cm (n=9)	<5.9 cm (n=9)
Quadriceps	Isokinetic concentric	35.9±13.8	44.9±25.6
	Isokinetic eccentric	108.5±47.9	115.6±49.1
	Isometric	45.7±18.7	50.1±36.0
Hamstrings	Isokinetic concentric	30.0±20.8	29.8±20.5
	Isokinetic eccentric	62.1±27.3	66.9±46.8
	Isometric	24.1±11.6	35.8±26.3

short trans-tibial stump, compromises the performance ability and level of the knee muscles activity during prosthesis usage.

Thigh muscle atrophy was determined by measurements of thigh girth. The measuring level was chosen where differences between thigh girth were greater, 18 cm proximal to the tibial tuberosity. Two groups of amputees were compared; those where thigh girth differences were greater than 5.9 cm and those with a difference smaller than 5.9 cm. Comparing values of muscles strength measured in these two groups, a general decrease in strength was noticed among those with a greater thigh muscles atrophy nevertheless, differences were not significant.

In conclusion, although most trans-tibial amputees manage their activities of daily living and conduct a fairly active life, strength of the amputated limb thigh muscles was found significantly reduced, especially in amputees with a short stump. In so far as the ultimate goal in the rehabilitation of amputees is to return the patient to an acceptable level of function, it is recommended that the amputee should be trained and encouraged in self strengthening exercises for the amputated limb thigh muscle. Stronger muscles will improve standing balance and quality of gait, especially among those with a short stump.

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