Isokinetic strength and endurance of the knee extensors and flexors in trans-tibial amputees

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Abstract

Significant levels of muscular fatigue alter the co-ordination patterns and the ability to accomplish proper daily functions, especially in patients with initial low levels of strength. The purpose of this study was to evaluate the strength and endurance of the quadriceps and hamstring muscles in trans-tibial amputees. Concentric strength and endurance of the thigh muscles were measured bilaterally by an isokinetic dynamometer. The measured variables were torque and angle. For the endurance test, a fatigue index was calculated. Peak torque for extension and flexion was significantly higher in the sound limb (p<0.01). The fatigue index for extension was not significantly different in the sound limb from the amputated limb. The fatigue index for flexion is significantly higher in the sound limb (p<0.01). The finding may imply that from a metabolic point of view, the muscles of the amputated limb function properly. It is of great importance to reduce the bilateral deficit and the degree of atrophy as soon as possible in order to improve the level of performance. By choosing a correct strength and endurance training programme, one may expect to get a significant and good reaction from the muscles of the amputated limb as is expected from training the muscles of a sound limb.

Introduction

Atrophy of the thigh muscles in the amputated limb is often observed among long-standing trans-tibial (TT) amputees. TT amputation of the limb results in loss of proprioceptive feedback, mainly from the ankle joint and related muscles. It is therefore accepted that the remaining limb on the amputated side of TT amputees is less active in daily functions of standing and walking (Isakov et al., 1996).

Manual muscular testing is widely used by clinicians in the assessment of patients’ functionality. However, it is recommended to employ quantitative methods, when an exact definition of muscular force is required, for purposes of either diagnosis or follow-up, especially in populations with pathology (Cabri and Clarys, 1991).

Isokinetic devices provide exact and reliable monitoring of strength, even at very limited ranges of muscular potential. Isokinetic muscular testing has distinct advantages over other modes of strength testing in that maximal torque can be generated throughout the whole range of motion (ROM). In addition, isokinetic dynamometers are relatively safe because the resistance is adjusted to the subject’s effort by the mechanism of the measuring device. When limiting factors, such as pain or discomfort, are suddenly introduced, the resistance is immediately adjusted to the patient’s effort and thus the risk of injury is minimised. Isokinetic testing procedures for concentric contractions of knee extensors and flexors were reported to be highly reliable across a wide range of angular velocities (Perrin, 1993). The value of isokinetic
testing for locomotor functional capacity has been established in the literature (Dvir, 1995; Baltzopoulos and Brodie, 1989).

Previous studies, which compared isokinetic strength between the thigh muscles of the amputated limb (with and without prosthesis) versus the sound limb, reported a significant higher strength in the sound limb (Renstrom et al., 1995; Klingentierna et al., 1990; Renstrom et al., 1983). These results are based on performance in non-fatigue conditions. Significant levels of muscular fatigue may alter the co-ordination patterns and the ability to accomplish proper daily functions. To function properly, a minimum level of strength is required. Under conditions of fatigue the strength of the lower limb muscles is reduced. In patients with initial low levels of strength that reduction may reach values below the minimum threshold which is required in order to accomplish the motor task.

The purpose of this study is to evaluate the isokinetic strength and isokinetic endurance of the knee extensors and flexors in trans-tibial amputees.

Methods

Eleven (11) subjects, with traumatic trans-tibial amputation volunteered for this study. Their mean age was 43.7 years (SD: 14.4 years) (range: 22 to 68 years). The mean time from amputation to the present study was 19.6 years (SD: 13.6 years) (range: 2.5 to 40 years). The stump mean length was 9.5cm (SD: 5.9cm) (range: 3.0 to 22.0cm), measured from the tibial tuberosity to the stump tip. All subjects were using a supra-condylar patellar-tendon-bearing socket without additional suspension device. All subjects were excellent walkers who used their prostheses on a regular basis and were not using any supportive aids for ambulation. No subject had any contracture or complaints of knee or stump pain during the test. The ethical committee approved the study. All subjects were informed of the study procedure and gave their informed consent.

The purpose of this study is to evaluate the isokinetic strength and isokinetic endurance of the knee extensors and flexors in trans-tibial amputees.
Table 1. Means (SD) of peak torques (N.m) and the mean deficit (SD) in the peak torque (%) of the amputated limb relative to the sound limb in the maximal strength test.

<table>
<thead>
<tr>
<th>Muscle group</th>
<th>Sound limb</th>
<th>Amputated limb</th>
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<tbody>
<tr>
<td></td>
<td>Mean peak</td>
<td>Mean peak</td>
</tr>
<tr>
<td></td>
<td>torque (SD)</td>
<td>Torque (SD)</td>
</tr>
<tr>
<td>Extensors</td>
<td>154.3 (45.0)</td>
<td>79.1 (40.3)</td>
</tr>
<tr>
<td>Flexors</td>
<td>74.6 (25.7)</td>
<td>49.3 (12.3)</td>
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with the sound limb by paired t-tests for the means of the two groups.

**Results**

Intraclass correlations were in the order of 0.97-0.98 for absolute and relative knee extension PT for each of the two legs. Means of PTs and the mean deficit in the PT of the amputated limb relative to the sound limb in the maximal strength test are presented in Table 1. PTs for both extension and flexion are significantly different from the sound limb (p<0.01). The PTs of the sound limb were relatively higher and the bilateral deficit in the PT is presented in Table 1.

Extensors and flexors FIs are shown in Table 2. Three (3) subjects exhibited a negative FI which indicate increased work output at later stages of the ET relative to its earlier stages. Those results where excluded from Table 2 and this phenomenon will be discussed later. A 10.9% difference in mean FI for extension was not significantly different in the sound limb compared with the amputated limb. The mean FI for flexion was significantly higher (mean difference of 46.7%) in the sound limb than in the amputated limb (p<0.01).

**Discussion**

The purpose of this study was to evaluate the isokinetic strength and isokinetic endurance of thigh muscles in trans-tibial amputees. All subjects had been completely rehabilitated following a traumatic amputation.

Subjects did not report any pain or discomfort during or following the testing sessions. In some cases subjects had difficulty in performing a smooth repetitive movement across the range of motion during the initial repetitions of the warm-up. However, all subjects overcame this difficulty within a few warm-up trails. None of the testing trials was affected by this phenomenon.

The individual results were quite heterogeneous probably due to different age groups, time since amputation and stump length. Nevertheless the variability is representative of the wide range of patients which compose the relevant population. Availability of fully rehabilitated subjects with long-term independent ambulatory experience was a major factor in the selection of the sample size. In spite of the fact that statistical tests that are based on a small sample size are relatively deficient with regard to statistical power, some of the results were found to be significant. The insignificant difference in mean FI for the extensors should be evaluated with consideration of the small sample size and with respect to the size effect of the difference between the means.

In spite of the fact that the subjects were independent and had a normal active life the maximal strength in the amputated limb was lower than he sound limb. The bilateral deficit in

Table 2. Means (SD) of the fatigue indexes (%) and the mean deficit (SD) in the fatigue index (%) of the amputated limb relative to the sound limb in the maximal strength test.

<table>
<thead>
<tr>
<th>Muscle group</th>
<th>Sound limb</th>
<th>Amputated limb</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean fatigue index (SD)</td>
<td>Mean fatigue index (SD)</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>Range</td>
</tr>
<tr>
<td>Extensors</td>
<td>34.4 (12.0)</td>
<td>*34.2 (18.9)</td>
</tr>
<tr>
<td>Flexors</td>
<td>*49.4 (7.0)</td>
<td>**26.3 (18.1)</td>
</tr>
</tbody>
</table>

*N=10   **N=9
maximal strength tests in a normal population is 10% (Perrin, 1993). In non-amputated populations with previous lesions or disuse a deficit of more than 20% is considered abnormal (Dvir, 1995). In all but one of the subjects the extension deficit was 30% or higher (Table 1). These results are consistent with previous reports on amputated subjects. (Isakov et al., 1996; Renstrom et al., 1983). The bilateral deficit may not be of functional concern during activities that demand sub-maximal strength levels. However, it may influence the motor patterns and the safety of the patient in activities which require high levels of strength endurance such as stair climbing, locomotion on steep slopes and carrying of loads.

The quality of gait and standing in TT amputees is related to the fitting of the prosthesis to the stump and to the strength of the thigh muscles (Isakov et al., 1996; Renstrom et al., 1983). Amputees with a good level of muscle strength are better walkers (Renstrom et al., 1995). In a review paper, Bagley and Skinner (1991) conclude that training to improve strength seems to be effective in improving amputee gait. In a normal population, the maximal voluntary contraction force of the knee extensor muscles increases up to age 27 years, remains stable until the age of 45 and then begins to decline gradually (Larsson et al., 1978). For aged people, 50-70 years old, the loss of strength is about 15% per decade (Rogers and Evans, 1993). It is reasonable to infer that after amputation it is of great importance to reduce the bilateral deficit and the degree of atrophy as soon as possible in order to improve the level of performance and establish strength reserves for older age. The current results suggest that long-term deficit in strength exists in rehabilitated subjects after many years of independent functioning.

Norms about fatigue rate are scarce in the literature. This may be partially attributed to the lack of uniform protocols of testing. Clarke and Manning (1985) report a isokinetic fatigue rate in healthy subjects of 40% at 2.1 rad.s⁻¹ after age 50. Ben-Sira et al. (1997) reported a FI of 30% to 50% in healthy subjects at 2.61 rad.s⁻¹. In the present study, the mean FI for quadriceps in the sound limb was 38.4% and in the amputated limb 34.2%.

Three (3) subjects failed to exhibit fatigue in some of the indices during ET and registered a negative FI. It is clear that the subjects failed to produce maximal efforts during the first few repetitions. It is possible that inhibition due to the maximal endurance demands influenced the subject to work sub-maximally at the early stages, in order to ensure completion of the entire task. It is also possible, that the early MTS was insufficient for these subjects, to develop complete confidence in the execution of the task. Thus, they used the early stages of the ET for further familiarisation which resulted in a learning effect. It is noteworthy that two of the subjects had a shorter period of time since amputation (2.5 years) which may be a factor in handling unfamiliar endurance tasks effectively. The trials with the negative FI were excluded from the analysis because they do not represent the phenomenon of fatigue and thus are irrelevant to the purpose of this study.

The results of the present study indicate that even though a significantly large PT bilateral deficit was found in knee extension between the amputated and the sound limbs, there are non-significant levels of FI bilateral deficit. This finding may imply that from a metabolic point of view, the muscles of the amputated limb function properly. Nevertheless, it is reported (Renstrom et al., 1995) that the main cause for muscle activity is the reduction of the fibre size since it was found that the mean muscle fibre area of the vastus medialis of the amputated leg was 74% of that of the sound leg. By choosing a correct strength training programme, one may expect to get a significant and good reaction of the muscles of the amputated limb as is expected from training the muscles of a sound limb. Therefore, it is recommended that veteran, TT amputees should be trained and encouraged in self-strengthening exercises for the amputated limb thigh muscles.

REFERENCES


Strength and advance of knee muscles in the trans-tibial amputee


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