A comparison of traditional prosthetic training versus proprioceptive neuromuscular facilitation resistive gait training with trans-femoral amputees

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Abstract
Reports in the rehabilitation literature suggest that patients with trans-femoral amputation ambulate well after suitable prosthetic treatment. The effects of exercise protocols on function, however, have not been documented in this population. This study was conducted to compare the outcome of traditional and proprioceptive neuromuscular facilitation (PNF) techniques on weight bearing and gait. Fifty unilateral trans-femoral amputees who were attending for their first prosthesis, participated in this study. Amputees were randomly assigned into groups receiving the traditional training or PNF. Traditional treatment was consisted of weight-shifting, balancing, stool-stepping and gait exercises. In the other group the same activities were given by PNF. Amputees were trained 30 minutes daily, for a total of 10 treatments. Pre- and post-training assessment included weight bearing measurements by using two bathroom scales and time-distance characteristics of gait from footprints. A statistically significant difference was found in all parameters within the groups due to pre- and post-training evaluation data (p<0.05), but more obvious improvement was observed in the group who received PNF (p<0.05). The results of the study suggest that the prosthetic training based on proprioceptive feedback was more effective to improve weight bearing and gait when compared with a traditional programme.

Introduction
Weight acceptance, single limb support and limb advancement are specific functional tasks in achieving a normal walking pattern. After amputation, the decrease in body weight will be accompanied by an alteration in the position of the centre of mass over the base of support and there will be inadequacy in the above mentioned three factors. Results will be; a decreased stance time on the prosthetic side, shortened stride length on the sound limb or lateral trunk bending over the amputated side. With a well planned prosthetic training programme after postoperative and preprosthetic physiotherapy approaches; the amputee can walk in a pattern closer to normal (Fernie, 1981; Gailey and Clark, 1992; Olsson, 1990; Skinner and Effeney, 1985; Whittle, 1991; Peters and Krumrey, 2000; Mattes et al., 2000).

This study was performed to compare the outcome of traditional and proprioceptive neuromuscular facilitation (PNF) techniques on weight bearing and gait biomechanics.

Subjects and methods
Subjects
Fifty unilateral trans-femoral amputees participated in this study. They were all male, traumatic amputees and were in the prosthetic phase of rehabilitation for their first prosthesis. Subjects signed an informed consent form before participating in the study. The mean time elapsed since amputation was 7.20 ± 0.76 months.
Table 1. Physical characteristics of the groups.

<table>
<thead>
<tr>
<th></th>
<th>PNF Group (n=25)</th>
<th>TPT Group (n=25)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>X ± SD</td>
<td>X ± SD</td>
<td></td>
</tr>
<tr>
<td>Age (year)</td>
<td>28.16±7.24</td>
<td>28.18±6.48</td>
<td>NS</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.73±0.07</td>
<td>1.72±0.06</td>
<td>NS</td>
</tr>
<tr>
<td>Body mass* (kg)</td>
<td>67.40±12.44</td>
<td>68.12±12.54</td>
<td>NS</td>
</tr>
<tr>
<td>LEL (cm)</td>
<td>88.48±3.28</td>
<td>87.94±3.42</td>
<td>NS</td>
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</tbody>
</table>

LEL = Lower limb length  
NS = Not significant  
* With prosthesis

were randomly assigned into groups receiving PNF (PNF Group) and traditional prosthetic training (TPT Group). Ages were between 20 and 40 years, with a mean of 28.16 ± 7.24 years in the PNF group and 28.18 ± 6.58 years in the TPT group. There was no muscle weakness other than the weakness related to the level of amputation. No muscle shortening, joint motion limitations or other problems preventing weight bearing and walking were the other selection criteria. All the subjects received postoperative and preprosthetic physiotherapy procedures including stump positioning, bandaging, stretching and dynamic exercises, balancing activities in parallel bars and finally three-point ambulation. Physical characteristics of the groups are given in Table1.

Methods

Modular prostheses including modified total contact quadrilateral socket, single axis knee joint with constant friction and Solid Ankle Cushion Heel (SACH) foot were utilised in the prosthetic fittings. To achieve the adequate functions of thigh muscles; the anteroposterior dimension of the socket was increased and the mediolateral dimension was decreased when compared with a standard quadrilateral socket (Fernie, 1981; Gailey and Clark, 1992).

After single axis knee joint and SACH foot were attached to the socket and biomechanical alignments were performed, the subjects were asked to walk freely in parallel bars for one day under supervision. Free walking was permitted to provide adaptation to prostheses before training.

Pre- and post-training assessment included weight bearing percentage on the amputated side and temporal- distance (TD) parameters of gait from footprints (Shores, 1980).

Gruendel's weight bearing method was utilised to determine the amount of weight borne on the amputated side. With the subject standing on two juxtaposed scales, minimal (Min WB) and maximal (Max WB) values were visually recorded on the amputated side for three consecutive minutes (Gruendel, 1992).

The average weight bearing on the amputated side (M1) was calculated by dividing the sum of maximal and minimal weight bearing values by two.

The percentage of total body weight (TBW) borne through the amputated limb was then determined using the formula:

\[(M1/TBW) \times 100\]

A 12m walkway was used to evaluate TD values of gait and the measures were recorded from footprints of the central 7m.

Patients were asked to walk with a self-selected comfortable pattern in all assessment except the evaluation of cadence during fast walking.

Cadence was assessed as the number of self-selected comfortable steps taken per minute and the maximal number of steps available per minute during fast walking.

Stride length was measured as the distance between two successive footprints of the same foot. Step length was measured as the distance between two successive footprints, amputated to sound heel and sound to amputated heel.

Step width was measured as the distance between the centre of the two heels.

Six footprints consisting of three successive right and left footprints were analysed. Four measurements of stride length and step width and two measurements of amputated and sound side step length were averaged for statistical analysis.

Velocity was calculated in centimetres per second by using the self-selected comfortable cadence as follows:

\[\text{Velocity (cm)} = \text{Step length } \times \text{Cadence} / 60\]
Prosthetic training with PNF in trans-femoral amputees

Table 2. Comparison of the groups for weight acceptance and gait parameters.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>PNF Group</th>
<th>TPT Group</th>
<th>a-b</th>
<th>c-d</th>
<th>a-c</th>
<th>b-d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before treatment (a)</td>
<td>After treatment (b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>X ± SD</td>
<td>X ± SD</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Weight bearing (%)</td>
<td>39.10±6.22</td>
<td>55.68±6.98</td>
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</tr>
<tr>
<td>Stride length (cm)</td>
<td>106.22±7.60</td>
<td>114.08±13.69</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amputated side step length (cm)</td>
<td>59.82±4.95</td>
<td>55.94±4.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound side step length (cm)</td>
<td>46.40±4.35</td>
<td>58.14±3.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step width (cm)</td>
<td>18.72±1.05</td>
<td>13.92±3.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSCG (steps/min)</td>
<td>58.12±8.79</td>
<td>74.32±8.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FG (steps/min)</td>
<td>63.12±8.79</td>
<td>84.32±8.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity (cm/s)</td>
<td>51.43±8.73</td>
<td>66.14±7.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SL/LEL</td>
<td>1.20±0.11</td>
<td>1.28±0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* P<0.05  
NS= Not significant  
SSCG= Cadence with self-selected comfortable gait  
FG= Cadence in fast gait  
SL/LEL= Stride length/lower limb length

To obtain the ratio of stride length to lower limb length (LEL); LEL was measured as the distance from the superior border of the greater trochanter to the floor bisecting the lateral malleolus.

Patients in the TPT group, were treated with traditional prosthetic training consisting of weight-shifting, dynamic balancing activities, stool stepping, braiding, gait exercises and climbing/descending the stairs (Gailey and Gailey, 1989; Gailey and Clark, 1992; Kerr and Brunnstrom, 1956). Forward - backward and side to side weight shifting exercises were given to the amputee so that he could experience the orientation of the centre of mass over the base of support.

To promote increased weight bearing on the prosthesis, single limb balance exercises were given (stool-stepping), while the sound limb was advanced.

Stepping forward and backward with the sound and prosthetic limbs, side stepping and braiding were taught to patients.

Braiding was given to improve prosthetic control, balance and coordination.

In the PNF group, in addition to free dynamic balance exercises static balance exercises were given.

While the patient tried to maintain his balance the physiotherapist gave resistance in an antagonistic direction. So during these activities the patient had to resist the physiotherapist by co-contraction and isometric contraction. These contractions gave a proprioceptive feedback that is different from the feedback attained through free unresisted balance exercises, as was given to the control group.

Also in the PNF group approximation was applied to restore the relationship between the prosthetic foot and the ground. During balancing, weight shifting, stool-stepping, single limb standing, gait and climbing and descending the stairs, approximation was used together with resistance. Approximation was applied to the weight bearing side, while resistance was given to promote the advancement of the other limb (Gailey and Gailey, 1989).

To make the group aware of movement, rhythmical initiation techniques were utilised while performing trunk rotation and pelvic motions. This improved arm swing and consequently balance, symmetrical gait and momentum (Gailey and Gailey 1989; Knott and Voss, 1968).

Prosthetic training of both groups initiated in parallel bars with double arm support and progressed to single arm support. When the amputee succeeded in performing the activities without support, training continued in an open area.
Table 3. The mean values of the differences of weight acceptance and gait parameters in the groups

<table>
<thead>
<tr>
<th>Parameters</th>
<th>PNF Group (Before-after treatment) X± SD</th>
<th>TPT Group (Before-after treatment) X± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight bearing (%)</td>
<td>16.59±8.87</td>
<td>8.35±3.47</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>7.86±3.89</td>
<td>1.32±0.56</td>
</tr>
<tr>
<td>Amputated side step length (cm)</td>
<td>3.88±1.86</td>
<td>5.42±2.27</td>
</tr>
<tr>
<td>Sound side step length (cm)</td>
<td>11.74±3.62</td>
<td>6.74±2.65</td>
</tr>
<tr>
<td>Step width (cm)</td>
<td>4.72±2.80</td>
<td>2.60±1.04</td>
</tr>
<tr>
<td>SSCG (steps/min)</td>
<td>16.44±4.58</td>
<td>9.96±2.26</td>
</tr>
<tr>
<td>FG (steps/min)</td>
<td>21.60±4.36</td>
<td>14.72±2.46</td>
</tr>
<tr>
<td>Velocity (cm/s)</td>
<td>14.72±3.81</td>
<td>9.60±3.60</td>
</tr>
<tr>
<td>SL/LEL</td>
<td>0.08±0.01</td>
<td>0.02±0.03</td>
</tr>
</tbody>
</table>

* P<0.05
SSCG= Cadence with self selected comfortable gait
FG= Cadence in fast gait
SL/LEL= Stride length/lower limb length

Data analysis
In this study, two groups were formed in order to compare the effects of PNF and conventional prosthetic training on the weight bearing and gait characteristics of trans-femoral amputees.

Student’s t-test was used to compare pre- and post-treatment gait and weight bearing data in each group and between the groups.
The alpha level was set at 0.05 (α = 0.05).

Results
When the physical characteristics were evaluated, the distribution of the patients was found to be homogeneous (Table 1).

Post-treatment weight bearing percent showed important increase in both groups when compared with pre-treatment values (p<0.05) (Table 2).

The gait parameters of both groups except stride length and the ratio of SL/LEL in the TPT group, were found to be improved when pre- to post-treatment results were evaluated (p<0.05) (Table 2).

The gait parameters of both groups except stride length and the ratio of SL/LEL in the TPT group, were found to be improved when pre- to post-treatment results were evaluated (p<0.05) (Table 2).

The gait parameters did not show any difference while post-treatment results presented significant differences in favour of the PNF group (p<0.05) (Table 2).

It was determined that the group which received PNF (PNF group), was more successful than the TPT group, when the pre- to post-treatment values were compared (p<0.05) (Table 3).

Discussion
Although the outcome of this study suggested that both therapeutic approaches were effective on weight bearing and gait biomechanics, better results were attained in the group who received proprioceptive feedback.

Maintenance of equal step length is the most difficult part of gait training in trans-femoral amputees. This uneven step length is usually related to inadequate weight bearing through the prosthetic limb (Gailey and Clark, 1992; Mattes et al., 2000; Kerr and Brunnstrom, 1958; Jones et al., 1997). In this study, with the increase in weight bearing percentage the amputated and sound side step length became closer. Sound and amputated side step length of trans-femoral amputees was reported to be 58 ± 7cm and 63 ± 7cm respectively by Murray et al. (1981). Results of the authors’ study was in accordance with Murray's research.

Stride length reached 114.08cm in the PNF group and 108.20cm in the TPT group. Stride length of the PNF group came closer to the expected normal values for trans-femoral amputees (Olsson, 1990; Skinner and Effeney, 1985; Whittle, 1991).

This was probably the result of the emphasis given on resistive stepping and gait techniques. At the beginning of treatment the step width was higher than normal in both groups. The group trained with PNF reached a better value, but this was still higher than the step width of normal adults which is to be expected.
Amputees in the PNF group reached a free cadence of 74.32 steps/min while the TPT group's cadence was 68.36 steps/min after the treatment. When cadence of non amputatedagemates are considered to be between 91-135 steps/min, the cadence gained by the PNF group was not excessively low (Zuniga et al., 1972; James and Oberg, 1973; Murray et al., 1981; Skinner and Effeney, 1985; Olsson, 1990; Whittle, 1991; Gailey and Clark, 1992; Jones et al., 1997). In the authors' opinion, when the amputee increases his speed, the prosthetic limb tends to take a longer step, thus increasing asymmetry. Therefore, instead of cadence concentration was on even step length during the training period.

The maximal steps taken per minute by the PNF and TPT groups were found to be respectively 84.32 and 78.36 in the groups after the treatment. Murray et al. (1981) reported an average cadence of 89 ± 3.0 steps/min in transtibial amputees. The study findings were very close to Murray's results.

Velocity was found to be increased to 66.14 cm/s in the PNF group and 61.63 cm/s in the TPT group. In the same study done by Murray et al. (1989); velocity of the trans-femoral amputees was found to be 78 ± 8.0 cm/s in slow walking.

They also utilised a constant friction knee mechanism. In the authors' study, the average post-training velocity of the PNF group advanced to a closer value.

It can be concluded that proprioceptive feedback is an effective way in achieving balance, symmetrical weight acceptance and gait in lower limb amputees.

The difficulties arising from inadequate awareness of functional tasks, because of the loss of the limb segment, could be taught and restored more easily with proprioceptive feedback. Traditional prosthetic training programmes are also valuable in reaching a functional gait pattern, but in the author's opinion if it is supported by PNF techniques, better results will be attained in rehabilitation.

REFERENCES


