GAIT IMPROVEMENT IN UNILATERAL TRANSFEMORAL AMPUTEES BY A COMBINED PSYCHOLOGICAL AND PHYSIOTHERAPEUTIC TREATMENT

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A conscious therapeutic approach was used combining methods in physiotherapy with psychological awareness to re-educate nine transfemoral amputees during 10 months in outdoor environments. All were rehabilitated trauma or tumour cases, mean age 33 years, and had worn their prostheses for more than 18 months. The method aimed at integrating the prosthesis in normal movements and increasing body awareness. Gait was measured with a three-dimensional motion analysis system. Self-selected comfortable and brisk gait speed increased from mean 0.95 m/s and 1.29 m/s before to 1.40 m/s and 1.65 m/s after treatment, respectively. The results remained at a 6-month follow-up. Before treatment three participants used walking-aids and all had problems with low-back pain. After treatment none needed walking-aids and almost all low-back pain had disappeared. Seven participants learnt to jog. Results indicate that this new approach may add skills, mostly on participation level, to lead a relatively normal life.

Key words: transfemoral amputees, physiotherapy, rehabilitation, gait improvement, gait speed.

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INTRODUCTION

Physiotherapeutic treatment of amputees traditionally focuses on physiological aspects like range of motion, strength, fitness (1) motor learning and recovery of function (2). The Roehampton model (3) is often used and describes physical training from very early stages after amputation to advanced gait training. Wahlborg-Kamwendo's rehabilitation model for amputees is used in physiotherapy education and in clinical applications in Sweden (4). Both describe traditional hospital-based gait training of unilateral transfemoral amputees in a similar way. Treatment aims at maintaining basic activities in daily life. Both rehabilitation models also suggest an average gait training period of 2 weeks with outpatient follow-ups. Other authors recommend similar models (5, 6).

Amputees have increased their demands to improve their quality of life (7). Few training methods have been developed to meet these demands and the challenge of technically improved prostheses. Advanced training and running patterns in transfemoral amputees have been described by Mensch & Ellis (8) and Mensch (9). Weight-bearing exercises, functional movements and skills are especially stressed (10, 11).

These rehabilitation programmes do not automatically include taking care of psychological problems, loss of identity, self-confidence and self-esteem (12), which may follow a severe body injury. The patients also need to adjust psychologically to their prostheses and to modify their body image (3, 4). The acceptance of an artificial replacement of a lost limb and the ability to integrate it functionally is a separate process (13). Most models of amputee rehabilitation referred to above emphasize an empathic approach. However, there is no description of what technique to use.

During the last decades several treatment models have developed in Sweden, mostly used in psychiatric physiotherapy (14). They aim at building up balance in both posture and muscular tone, thereby facilitating improved mental and emotional balance. Other aspects of this approach are to take deliberate action to create a working-alliance, i.e. a good working climate of sympathetic understanding and trust (15). This is achieved by techniques normally used in psychiatric therapy for example relating to the patient with empathy, giving warm mental support, using precise frameworks and keeping up regular contact (16). The therapist should maintain a neutral and professional attitude, acting only as a mirror, reflecting what is obvious, leaving interpretation to the patient (17).

The purpose of this study was to describe the principles of a new training method and evaluate this approach by means of gait measurements.

MATERIALS AND METHODS

Subjects

Within the healthcare districts of Helsingborg-Landskrona-Lund in south-west Sweden, all patients, aged 16–60, with a prosthesis resulting from unilateral transfemoral amputation caused by trauma or tumour were invited. All had to understand written and spoken instructions in Swedish. Sixteen persons met the criteria. One was excluded for medical reasons, one failed to participate in treatment due to his working situation and three died before the start. Two persons interrupted treatment due to an altered family or working situation. Five men and four women completed the treatment and follow-up.

The amputation was caused by tumour in four women and one man. Two men had been in motorcycle accidents and two had been injured at work. All had been amputees since in mean 10 years (range 3–27) and had worn their prosthesis for more than 18 months. Mean age was 33

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Table I. *Description of transfemoral amputees (n = 9), M = male, F = female*

Case no.	Weight (kg)	Height (m)	Gender M/F	Year of amputation	Cause	Amputated side	Age at inclusion (yrs)	Years since amputation at inclusion
1	50.5	1.58	F	1991	Tumour	R	16.5	5.0
2	66.0	1.60	F	1979	Tumour	R*	34.0	16.0
3	62.0	1.60	F	1991	Tumour	L**	49.5	4.5
4	81.5	1.67	F	1967	Tumour	R**	51.0	27.0
5	66.5	1.91	M	1982	Trauma	R	40.5	13.5
6	68.0	1.86	M	1988	Tumour	L	28.0	7.5
7	78.0	1.85	M	1990	Trauma	L	24.0	6.5
8	106.0	1.90	M	1992	Trauma	L	33.5	3.0
9	64.0	1.79	M	1990	Trauma	L	23.0	4.5
Mean	71.0	1.75					33.0	9.7

* Used two crutches before treatment.
** Used one stick before treatment.

years (range 16–51) (Table I). The prosthetic components and stump lengths (18) are shown in Table II. All had completed a conventional rehabilitation and were considered stable in their prosthetic use. One had a half disablement pension and the others were working or studying full time. All kept their prosthesis (Table II) throughout the period including the follow-up. The prosthesis was serviced and only worn out parts were replaced.

All participants were independent community walkers. Two amputees used one stick and one used two crutches before treatment. At the first evaluation they all had a similar impaired gait-pattern. Stance-phase was shorter and step-length was longer on the amputated side compared to the intact. During swing-phase on the amputated side they bent the trunk laterally towards the intact leg and during stance-phase towards the amputated side, creating a double limping. The prosthesis was thrown forward with a kicking-like movement during vaulting, i.e. heel-raise on the intact foot. They all managed well indoors, but reported fear of being pushed and loosing their balance in crowds. On even and hard ground all walked with heads slightly bent down, to carefully observe the ground as they could not perceive the surface or the position of the prosthetic foot. Coordination between upper and lower body was poor. Turning around in a safe way was possible only towards the intact side. Everyone lost their balance if walking and trying to turn the head and shoulders.

Everyone reported low-back pain almost every day and very often to a degree that stopped them from carrying out their daily plans. It was described as stabbing when moving and aching while resting.

Methods

Principles for the training programme. The purposes were to create confidence and trust towards the prosthesis and to integrate it into movements, to normalize and achieve freedom of movement including running and jumping and to reduce low-back pain.

Centre of gravity should be placed in the centre of the body and an altered awareness of body and movement was also required. Basic training of motor functions was performed, e.g. to alter gait-speed, to turn round in both directions, to cope with different surfaces, terrain and weather, climbing and descending hills and stairs and crossing pavements. The individual training programme consisted of components selected and combined from several theories in physiotherapy ranging from basic to more advanced skills:

1. always training out of doors in different environments and terrain;
2. exercises containing combination of steps, rotations and arm-movements to improve strength, fitness, coordination and postural control;
3. specially designed and selected movements to regulate exercise intensity, increase endurance and flexibility;
4. activation of postural muscles to find the centre-line and retain it while moving;
5. a therapeutic climate permitting both positive and negative emotional expressions;
6. training of perception and cognitive ability during movement;
7. the use of a conscious therapeutic approach.

The training procedure. Several theories of body awareness originating from Swedish psychiatric physiotherapy (14) were combined to a conscious therapeutic approach. Their mutual components were to activate postural muscles, aimed at finding the centre-line and retaining it while moving in order to maintain and keep a proper alignment, to integrate the respiration functionally into the movement and also to use

Table II. *Stump length, socket and prosthetic components in nine transfemoral amputees*

Case no.	Stump length ISO standard*	Socket	Knee	Foot**
1	Average	Ischial containment	Total knee mechanic	Seattle foot
2	Short	Quadrilateral	Aqua pend	Flex foot
3	Short	Quadrilateral	Total knee mechanic	Flex walk
4	Average	Quadrilateral	Total knee mechanic	Multiflex ankle Seattle foot
5	Long	Quadrilateral	Hydraulic Växjö knee	Multiaxis Växjö foot
6	Average	Ischial containment	Hydraulic Mauch knee	Flex foot
7	Long	Quadrilateral	Pneumatic T-Ling	Flex walk
8	Average	Quadrilateral	Pneumatic Aqua pend	Flex foot
9	Average	Ischial containment	Pneumatic Aqua pend	Flex foot

* Short means length less than width at the base, long means length more than twice the width at the base and average means stump length between 1–2 times the width at the base of stump (18).
** All prosthetic feet are energy-storing.

Table III. *Self-selected comfortable and brisk walking speed (m/s) in transfemoral amputees before and after treatment and at 6 months' follow-up*

	Comfortable speed (m/s)			Brisk speed (m/s)		
Case no.	Before	After	Follow-up	Before	After	Follow-up
1	1.22	1.50 (22)	1.39 (14)	1.58	1.81 (15)	1.75 (11)
2	0.78	1.17 (50)	1.11 (43)	1.00	1.47 (47)	1.53 (53)
3	0.69	1.14 (64)	1.19 (72)	0.89	1.36 (51)	1.33 (49)
4	0.69	1.19 (72)	1.28 (84)	1.11	1.50 (35)	1.47 (32)
5	1.08	1.50 (38)	1.53 (41)	1.44	1.83 (27)	1.81 (26)
6*	1.31	1.78 (36)	1.56 (19)	1.58	2.06 (30)	1.81 (15)
7	1.39	1.67 (20)	1.56 (12)	1.81	1.97 (9)	2.06 (14)
8	0.69	1.19 (72)	1.39 (100)	0.97	1.44 (48)	1.61 (66)
9	0.67	1.45 (79)	1.50 (86)	1.19	1.39 (17)	1.44 (21)
Mean speed (m/s)	0.95	1.40	1.39	1.29	1.65	1.65
SD	0.30	0.24	0.17	0.33	0.27	0.23
Mean improvement (%)		50	52		31	32
SD		22	34		15	20

Improvement is calculated as a percentage, in parentheses.
SD = standard deviation.
* Technical problems with the prosthesis at 6 months' follow-up.

very simple exercises to build movement sequences. These exercises were shown to the participant who then imitated the therapist. Without verbal corrections the participant had to discover the movement and the variations in performance. This discovery is an individual process and can not be hastened (14).

Exercises and movements were individually combined. Treatment was regularly scheduled at weekly intervals, always the same time and day of the week, for about one and a half hours. Every treatment session started with the therapist asking what had happened during the week. The answer served as a guide to the therapist to choose intensity and degree of difficulty of the first exercise. If the participant had had a really poor week, the treatment would start with exercises that the participant especially enjoyed or performed really well, this in order to raise self-confidence and acquire full focus on the training and perception of the movement. All treatment sessions were conducted by one physical therapist (CS), especially trained and experienced within psychiatric and orthopaedic care. The treatment period averaged 10 months (range 7–14). In two cases treatment was interrupted for 5 and 6 weeks, respectively, waiting for parts required to repair the prosthesis.

Every session was evaluated by the therapist and the participant together, but no specific homework was assigned. The treatment continued until the participant performed the complicated sequenced tasks without hesitating or stopping.

A conscious therapeutic approach. Using a conscious therapeutic approach meant among other things to stay neutral, not to make therapeutic predictions or other promises that could not be kept. It also implied refraining from trying to soothe the patient's anxiety or trying to cheer the patient up. Trying to persuade a patient to "look at things from the bright side" negates the sense of reality and implies that the patient's problems are small and nothing to worry about (17).

To stay neutral also meant to act as a mirror to what was being said and what was being performed. If, for example a participant would claim to have been practising all week and the therapist noticed that there was no improvement that could match such an effort, the therapist would say "I hear what you say, but my eyes tell me something else". This statement has no judgement or value but gives room for interpretation by the participant, either he/she has not trained or trained in the wrong way. It may explain to the participant that good results depend not only on the therapist or the participant, but are mutual achievements based on trust and understanding.

During training all feelings were allowed to be shown and were mirrored by the therapist. These feelings could be happiness and joy, but they could also contain fear of failing, anger and frustration directed toward the prosthesis or the therapist. When feelings were positive all credit and praise belonged to the participant. Negative ones were handled by the physiotherapist while remaining neutral and acting again as a mirror saying "I notice that you are upset, can you tell me what you are feeling or what you are thinking?"

Gait-analysis. Gait-analysis was performed by observation, video-recordings and by use of a VICON 370 (version 1.2, Oxford Metrics Ltd, Oxford, UK), a three-dimensional motion analysis system consisting of five infrared cameras, a Kistler force-plate (a piezoelectric transducer, type 9284) and a data-station (Pentium II, 350 MHz processor). Twenty-two special lightweight surface markers were attached directly to the skin bilaterally and placed over standardized anatomical landmarks. All recordings were done before and after treatment and at the follow-up after 6 months.

The gait-path was 12 m long. In the centre the force-plate was built in at floor level and covered with a thin rubber carpet to avoid influence of targeting effects. Participants were asked to walk at self-selected comfortable gait-speed. Recordings of five strikes on the force-plate of the healthy and the amputated leg, respectively, were made. The participant was then asked to walk with self-selected brisk gait-speed and recordings were made of another five strikes on the force-plate of the healthy and the amputated leg, respectively.

The system tracked gait events like stride-length and cadence from which gait-speed was calculated. Gait-speed was calculated as the mean speed of the first three trials at self-selected comfortable and brisk speeds, respectively. The mean speed was chosen as no signs of intra-variations in gait-speed were found before or after treatment or at follow-up after 6 months. The standard deviation (SD) of each session, both at comfortable and brisk speeds, varied from 0.00 to 0.08 m/s.

The participants' own opinions on their gait were assessed from interviews performed by CS before and after treatment.

RESULTS

After treatment the gait pattern in all participants was almost symmetric and body-weight was equally distributed between the amputated and the intact side during standing and walking, assessed by observation and video-recordings. None of the participants needed walking-aids any more, even when out-doors. The prosthesis was integrated in the movements. Vaulting disappeared after treatment although there was a slight tendency for this to re-appear at follow-up. In addition, seven participants learnt to jog using their ordinary prosthesis.

Self-selected comfortable gait speed increased in mean from

0.95 m/s before to 1.40 m/s and 1.39 m/s after treatment and at follow-up, respectively. This improvement ranged from 20% to 79% (mean 50%) comparing before and after treatment. At follow-up the improvement remained at 52% compared to before treatment (Table III).

Self-selected brisk gait speed increased in mean from 1.29 m/s before to 1.65 m/s after treatment and remained at that level at follow-up. Improvement of self-selected brisk gait speed was in mean 31% and 32% after treatment and at follow-up, respectively, compared to before treatment (Table III).

The participants reported that they could perceive the surface and the position of the prosthetic foot better during stance-phase and they no longer felt a need to constantly observe the ground, not even in high grass or among wet leaves.

With improved gait-technique, walking skills and the ability to use the prosthesis functionally, the participants gradually started to feel in control of the prosthesis and thereby learned to trust it. No participant had any secondary problems with low-back pain after treatment or at follow-up.

Participants reported shopping for their clothes themselves for the first time since the amputation, going to outdoor concerts, attending festivals and dancing for the first time in years—and having fun doing it. They reported an increased freedom of choice, increased self-confidence and an improved quality of life.

DISCUSSION

Although the participants differed in many ways they all shared the same impaired gait-pattern before treatment, in which the prosthesis seemed to be disconnected from awareness of body and movement. This was interpreted as a psychological reaction to both the cause of amputation and the loss of the limb (12, 19). Although none of the participants showed any apparent symptoms or otherwise signs of psychological illness, this combination of physiotherapeutic treatment was chosen.

The most important explanation for the remarkable outcome is probably that the treatment period was regarded as a process, which is a consequence of applying a holistic perspective. To learn a new movement pattern and motor control, without normal inputs from proprioceptors in joints, muscles, skin and foot-sole is an ongoing process (2) of adapting to the amputation and the prosthesis, as well as facing social and other consequences (3, 4).

The deliberate use of a conscious therapeutic approach was also a contributing factor, though very hard to measure. All participants had experienced several treatments. One of the most important differences, according to the participants, was that they now felt respected as individuals.

Normalized gait-pattern and gait-speed can be explained by improved gait technique and improved body awareness including integration of the prosthesis. The attained results concerning gait speed were comparable with those of Perry (20). The participants increased their activity level during the treatment period and continued on this higher level throughout the follow-up. This meant that their prostheses in some cases wore out during the observation period and these normally would have been exchanged for newer ones. Especially one man was affected by this fact, but he agreed to continue with his old prosthesis in order to complete the study although technical problems may have lowered his performance at follow-up.

An amputated person consumes more energy compared to a non-amputee and energy consumption increases with higher levels of amputation (21). Exercise intensity is therefore adjusted to the level of amputation in conventional rehabilitation. The higher the level of amputation the lower the intensity during training as a result of the increased energy consumption (3, 4). This may explain why the aims of conventional rehabilitation are basic daily activities and seldom include the participation level according to the World Health Organization (22). The combined treatment made it possible for the subjects to take full advantage of their skills in a social context. Before treatment all participants were avoiding social events where people were gathering, e.g. going shopping or dancing, for fear of being pushed and loosing their balance. During the treatment period all these situations were spontaneously tried out and successfully managed by the participants. This active mobile life style is natural for almost every adult person, but has hitherto been impossible for our relatively young, amputated participants. The improved gait speed as well as the normalized gait pattern also had the effect that the participants felt less stigmatized socially.

For the seven participants who learnt to jog, this experience was exceedingly positive. They reported before treatment that the ability to jog was the function that they had missed the most. However, the goal of learning to jog was not to become a skilled jogger or sprinter. For such a purpose a special, individually adjusted prosthesis is required. The goal was to alternate gait-speed and to have the ability for example to catch a bus if necessary and this achievement gave a feeling of freedom of choice and an improved quality of life.

Before treatment all subjects reported problems with low-back pain, which has been shown to be significantly more common in transfemoral amputees (71%) compared to the general population and was rated even more bothersome than phantom limb pain or stump pain (23). After treatment almost all low-back pain had disappeared, which also indicates a more symmetrical and normalized gait pattern. We did not anticipate the long-lasting effect of the treatment on low-back pain and we did not realize that it would reduce pain to this extent. In a prospective study the effects on low-back pain should be measured more accurately.

All training took place outdoors regardless of weather, which probably was an added contributing factor to the remarkable outcome. This meant that training could be extremely varied, taking maximum advantage of the terrain, weather and environment. The choice of different environments also had positive, psychological effects. Most of the participants had not been to a sandy beach, wood or similar recreation areas since the amputation and the environment itself contributed to create a joyful atmosphere.

The treatment time may be seen as too generous, especially when comparing with conventional rehabilitation of amputees. However, the approximated cost of the total period of treatment was equivalent to about one fourth of the total cost for one prosthesis. Other studies of complicated injuries, for example of the anterior cruciate ligament have also found that a rehabilitation period of 6 months is required for optimal results (24).

We invited all the amputees that were eligible at that time in our area. Because of their wide range in age and cause of amputation we chose to develop this method in a continuous uncontrolled series. However, in the future it would be of interest to evaluate this method by an unbiased observer in a controlled study.

CONCLUSION

This combination of psychological and physiotherapeutic treatment has led to considerable gait improvement in this group of transfemoral amputees. Further controlled studies are needed to show if this effect can be generalized.

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REFERENCES

1. Brunnstrom S. Brunnstrom's clinical kinesiology. 5th ed. Philadelphia: F. A. Davis Company, 1996.
2. Shumway-Cook A, Woollacott M. Motor control. Theory and practical applications. Baltimore: Williams & Wilkins, 1995.
3. Engstrom B, van der Ven C. Physiotherapy for amputees. The Roehampton approach. 2nd ed. Singapore: Churchill Livingstone, 1993.
4. Wahlborg-Kamwendo K. Rehabilitering efter benamputation (Rehabilitation after leg amputation). Lund: Studentlitteratur, 1979; (In Swedish).
5. Ham RO. Early management: the therapist's role. In: Murdoch G, Bennett Wilson A Jr, eds. Amputation. Surgical practice and patient management. Bath: Butterworth-Heinemann, 1996; 370–375.
6. Edelstein JE. Later management: the therapist's role. In: Murdoch G, Bennett Wilson A Jr, eds. Amputation. Surgical practice and patient management. Bath: Butterworth-Heinemann, 1996; 376–382.
7. Kegel B. Adaptations for sports and recreation. In: Bowker JH, Michael JW, eds. Atlas of limb prosthetics: surgical, prosthetic, and rehabilitation principles. St Louis: Mosby Year Book, 1992; 623–654.
8. Mensch G, Ellis PE. Running patterns in transfemoral amputees: a clinical analysis. Prosthet Orthot Int 1986; 10; 124–134.
9. Mensch G. Lauftraining nach Beinamputation. Krankengymnastik 1993; 45; 979–986.
10. Mensch G. Exercise for amputees. In: Basmajian JV, Wolf SL, eds. Therapeutic exercise, 5th edn. Baltimore: Williams & Wilkins, 1990; 251–276.
11. Mensch G. Gehschulung nach Beinamputation. Krankengymnastik 1993; 45; 968–978.
12. Shontz FC. The psychological aspects of physical illness and disability. New York: Macmillan Publishing Co Inc, 1977.
13. Merleau-Ponty M. Phenomenology of perception. 10th edn. London: Routledge, 1989.
14. Mattsson M, Mattsson B. Physiotherapeutic treatment in out-patient psychiatric care. Scand J Caring Sci 1994; 8; 119–126.
15. Luborsky L. Principles for psychoanalytic psychotherapy. A manual for supportive/expressive treatment. New York: Basic Books Inc, 1984.
16. Sivik T. Dynamisk psykoterapi (Dynamic psychotherapy). Lund: Studentlitteratur; In Swedish 1990.
17. Everstine DS, Everstine L. People in crisis: Strategic therapeutic interventions. New York: Brunner/Mazel, 1983.
18. International Standards Organization, ISO 8548-2, Prosthetics and orthotics–Limb deficiencies–Method of describing lower limb amputation stumps. Geneva, 1993.
19. Weisman AD. Coping with cancer. New York: McGraw Hill Inc., 1979.
20. Perry J. Gait analysis. Normal and pathological function. Thorofare: SLACK Incorporated, 1992.
21. Waters RL, Perry J, Chambers R. Energy expenditure of amputee gait. In: Moore WS, Malone JM, eds. Lower extremity amputation. Philadelphia: Saunders, 1989; 250–260.
22. ICIDH-2: International classification, beta-2-draft, Full Version. Geneva: World Health Organization, 1999.
23. Smith DG, Ehde DM, Legro MW, Reiber GE, del Aguila M, Boone DA. Phantom limb, residual limb and back pain after lower extremity amputations. Clin Orthop 1999; 361; 29–38.
24. Zätterström R, Fridén T, Lindstrand A, Moritz U. The effect of physiotherapy on standing balance in chronic anterior cruciate ligament insufficiency. Am J Sports Med 1994; 22; 531–536.