J Int Acad Phys Ther Res 2018; 9(1): 1398—1405
ISSN 2092-8475
www.iaptr.org
https://doi.org/10.20540/JIAPTR.2018.9.1.1398

The Effects of Heel Off Stairway Walking Exercise on Ankle Muscle Activity and Static Balance of University Students With Ankle Instability

The purpose of this study was to investigate the effect of heel off stairway walking exercise on the increase of muscle activity and balance activity of the ankle joint muscles
in university students with functional ankle instability. The conservative treatment for the control group consisted of stairway walking (n=10) and the experimental group consisted of heel off stairway walking (n=11). The therapeutic intervention of the control and experimental groups was performed a total of 12 exercise sessions, 3 times per week for 4 weeks. To compare the two groups, the level of ankle disability was assessed by using the EMG, BT4 and Pedoscan in pre-treatment and post-treatment. Muscle activity increased in both the experimental groups and control groups in each group, however there was no significant difference between the groups. Balance ability did not show any significant difference. This study demonstrates that heel-off stairway walking is effective in significantly increasing muscle activity, however did not significantly improve balance ability.

Key words: *Ankle, Balance, Heel off, Stairway, Walking*

Hyung Min Oh[a], Bum Chul Jung[a], Byeong Jo Kim[b], Ye Ju Kang[a], Ji Eun Lee[a], Kyung Tae Yoo[a]

[a]Namseoul University, Cheonan; [b]Dongeul University, Busan, Korea

Received : 19 January 2018
Revised : 10 February 2018
Accepted : 15 February 2018

Address for correspondence
Kyung Tae Yoo, PT, Ph.D
Department of Physical Therapy, Namseoul University, 91, Daehak-ro, Seonghwan-eup, Seobuk-gu, Cheonan-si, Chungcheongnam-do, Republic of Korea
Tel: 82-041-580-2530
E-mail: taeyoo88@nsu.ac.kr

INTRODUCTION

Balance ability is the degree in which the body is able to maintain stability when subject to various perceptual, visual, and other such external stimuli that register as joint and muscle sensations. The ability to regain stability and control equilibrium during duress is a basic and necessary motor function. Maintaining the center of gravity within the body's base requires continuous postural control and a process of adaptation [1].

The ankle joint is composed of many complex segments and performs important biomechanical functions such as absorbing shock, controlling balance as well as stability while walking [2]. As things go, the ankle joint is one of the most commonly injured joints in athletes and civilians alike; in particular, sprains take up 75% of ankle injuries [3]. After ankle sprains, around 40% of patients experience anatomical instability, reduced ankle joint proprioception, weakened calf muscles, and functional ankle instability [4]. In cases of functional ankle instability as such, flawed postural control results in recurring instability and swaying [5]. This phenomenon often occurs when walking on uneven surfaces, going up and down stairs, and turning around on one foot. There's a sudden change in direction or halt and landing after a jump which may lead to further injury or cause chronic disorders [6]. Furthermore, the ankle joint is the first to step in postural control strategy as muscle contractions initially restore standing balance through ankle joint strategy [7]. The coordination of the ankle joint muscles in particular control sway when standing or walking and aid in keeping the center of gravity within the body's base [8]. Of these, muscle weakness in the calf muscles and tibialis anterior correlate heavily with ankle instability [9]. Wolfson et al. [10] stated that loss of balance was related to muscle weakness, and as such during rehabilitative training for functional ankle instability, Tropp.[11] emphasized strengthening the calf muscles and Ebig et al. [12] noted the importance of strengthening the tibialis anterior. MacIntyre et al. [13] and Dorsch et al. [14] stated that significant ankle strategy activity is necessary in order to maintain balance in postural sway between the tibialis anterior and calf muscles; furthermore, the muscle strength of the tibialis anterior and calf muscles correlate highly with balance and motion capability. Gefen [15] stated that the weakness of the peroneus longus causes abnormal centering of foot pressure where it is outwardly displaced causing frequent ankle sprains. Furthermore, when the tibialis anterior and calf muscles are put under continuous fatigue, the calcaneus and metatarsals bear the brunt of the body weight, causing further instability and lack of balance.

Standing with heel off is more imbalanced than when standing with feet flat on the floor. Clinically it is performed with both the front and back legs which have a relationship with postural stability, vertical power, and activity of the tibialis anterior. Furthermore, standing with heel off increases the activity of the medial and lateral muscles for side to side balance. In particular, the tibialis anterior is an important muscle as it performs dorsiflexion, provides a pushing force to the lateral side of the foot against the ground, and causes the ankle joint to become rigid [16]. Cho and Choi [17] state that when standing upright, an increase in the degree of foot flexion resulted in the increase of the muscle activity of the leg muscles. In particular the tibialis anterior, calf muscles, and biceps femoris all experienced an increase in activity when the angle of foot flexion exceeded 10 degrees. This suggests that the instability of standing with heel off leads to an increased dependence and activity of the leg muscles.

It should also be considered that stairs are a commonly utilized method of transport. In recent times, stairs have even come to be recognized as a tool for aerobic exercise and a source of everyday musculoskeletal exercise [18]. Seo and Jang [19] state that as using stairs requires constant balance whilst moving horizontally as well as elevating vertically, greater leg muscle strength is needed and therefore one is able to achieve both highly effective aerobic exercise and musculoskeletal exercise. Flynn [20] reports that when using stairs there is a larger range of joint movement than when walking on a flat surface and therefore using the stairs is instrumental when needing to increase leg muscle activity. Furthermore, while going up stairs, the amount of surface contact is directly related to the acceptance of somatosensory information received by the feet. Mercer and Sahrmann [21] state that when using stairs there is a difference in surface width and there may be appearances of biomechanical changes while performing the task. Lee et al. [22] also suggested that depending on changes on the surface, there is an increase in instability and in order to obtain stability, the activity of the leg muscles undergoes changes as well.

However, most previous studies regarding use of stairs focus on the change in leg muscle activity after using single step stairs. Few studies focus on the use of stairs themselves as a form of exercise. Furthermore, studies that have investigated the effect of increased muscle activity on balance ability are even more scarce. The results of this study will hopefully be useful as a primary resource for effective rehabilitation treatments.

This study aims to investigate the effect of going up and down stairs with heels off, on the activity of the muscles surrounding the ankle joint and static balance ability in university students in their 20s with functional ankle instability. Hopefully the study will be able to put forth an effective intervention method in the future.

The hypotheses for this study are as follows. First, performing the task of going up and down stairs with heels off will increase the activity of the muscles surrounding the ankle joint in university students with functional ankle instability. Second, performing the task of going up and down stairs with heels off will improve the static balance in university students with functional ankle instability.

SUBJECTS AND METHODS

Subject and Duration

The subjects of this study were thoroughly informed on the aims and methods of the study before providing consent of participation. The subjects of this study were male and female university students with chronic pain and ankle instability from 'N' University in Cheonan City of Chungnam Province. The subject selection criteria were as follows: those who had sprained their ankle more than once and could not support their weight, those that had suffered repeated injuries after the first sprain leading to long-term functional instability and discomfort, those with a score of 25 points and less on the Cumberland Ankle Instability Tool (CAIT), and those that had not suffered an ankle injury in the last 3 months. Subjects with a medical history including ankle joint fracture or surgery, as well as those with a nerve disorder related to the ankle joint were excluded. Individuals that satisfied at least one of the aforementioned selection criteria were admitted to participation in the study. Of the 24 selected subjects, 3 left the study due to personal reasons. Of the remaining 21 subjects, 11 were allocated to the experimental group and 10 were allocated to the control group. The study lasted for 4 weeks with each exercise session lasting 30 minutes and being performed 3 times a week. The subjects performed the exercises under the supervision of a researcher.

Measurement Apparatus

Ankle Joint Muscle Activity Measurement

In this study, the BTS FREE EMG (BTS, Italy) was used to measure the activity of the muscle surrounding the ankle joint 〈Table 1〉. An EMG is the electrical activity of a muscle and a wireless surface EMG is able to capture and record on a computer the electrical activity produced by the muscle through sensors applied on the skin. Through a survey, the injured ankle of each subject was identified and the sensors were applied onto the affected side. Areas in which the sensors were applied included the tibialis anterior ⅓ of the way between the distal end of the tibia and the medial malleolus, the peroneus longus ¼ of the way between the distal end of the tibia and the lateral malleolus, and the gastrocnemius at the most pronounced area [23, 24]. The criterion of measurement was the maximum voluntary isometric contraction (MVIC). In order to obtain an accurate measurement, each muscle was measured twice for a period of 5 seconds in which the measurement obtained at the third second was used. To ensure that every subject performed maximal isometric contractions, verbal encouragement was used [25].

Table 1. Measurement Apparatus

Equipment name	Manufacturer(Country)	Field of measurement
INBODY 720	Biospace(Korea)	Body composition analyzer
BSM 330	Biospace(Korea)	Automatic height meter
BTS FREE EMG	BTS(Italy)	Surface muscle activity
Balance Trainer BT4	HUR labs(Finland)	Posture adjustment meter
Pedoscan	Diers(Germany)	Foot pressure meter

Passive Balance Ability Test

1. Passive Balance Ability
   The BT4 (HURlabs, Finland) was used in order to measure static balance. The BT4 was used to measure the postural fluctuation index when standing on the left and right legs 〈Table 1〉. Before measurement, the posture was explained to the subjects. Subjects stood on the marked area with one leg while the other leg was flexed at the knee and slightly flexed at the hip. The measurement lasted for 30 seconds and each leg was measured once with a minute rest between each measurement [26].
2. Center of Gravity Range of Movement
   The Pedoscan (Diers, Germany) was used in order to measure balance by observing the area of movement of the center of gravity 〈Table 1〉. Subjects stood comfortably on the machine with the feet bare and shoulder width apart. The measurement lasted 15 seconds and the movement of the center of gravity was measured through both feet.

Stairs

The stairs used in this study had a height of 17 cm and a width of 189 cm.

Research Method

21 subjects took part in this study with 11 divided into the experimental group and 10 into the control group. Both groups commenced the exercise program after completing pre-intervention measurements and under direction from a researcher. As a warm up, both groups performed a knee and ankle active joint range of motion exercise for 5 minutes. After the warm up, 1 set of going up and down the stairs 10 times was performed for a total of 3 sets [27]. In order to prevent muscle fatigue there was a 2 minute break between sets [28]. The exercise was done 3 times a week

for 4 weeks. The velocity in which the stairs were to be used was determined by normal gait on a flat surface [29]. To maintain exact pace, a metronome was used (108 steps/min) in order to direct the speed of the subjects [16]. The experimental group was to go up and down the stairs with heels off and at as much of an angle as possible without injury. For the cool down exercise, the same method was used as the warm up. The control group performed the same task with the same conditions as the experimental group, except with feet flat on the surface of the stairs 〈Table 2〉. After the 4 week duration, the muscle activity around the ankle joint and static balance ability was measured again for comparison with the pre-intervention measurements during data analysis.

Table 2. Exercise Program

	Experimental group	Control group
Warm up	Active Range of Motion Exercise 5 minute	Active Range of Motion Exercise 5 minute
Main Exercise	heel-off stairway walking exercise 1 set / 10 rep, total 3set Break between each set 2 minutes	Whole footsteps stairway walking exercise 1 set / 10 rep, total 3set Break between each set 2 minutes
Cool-down	Active Range of Motion Exercise 5 minute	Active Range of Motion Exercise 5 minute

Data Analysis

SPSS Ver 20.0 for Windows was used for data analysis. The independent t-test was used to test for homogeneity in the general characteristics between the two groups. The paired t-test was used to test for statistical significance in muscle activity and static balance within each group. In order to determine the effect of each exercise on muscle activity and static balance between the groups, the pre-intervention values were subtracted from the post-intervention values and then the results were put through an independent t-test. Statistical significance for all results were set as $p<.05$.

RESULTS

Homogeneity Test for a Subject's General Characteristics

The pre-intervention measurement for both groups regarding height, weight, and BMI showed no significant differences after undergoing an independent t-test 〈Table 3〉. As such the study commenced with knowledge that both groups were homogenous.

Comparison of Muscle Activity

The comparison of the activity in the ankle joint muscles (tibialis anterior, peroneus longus, gastrocnemius) between the groups are shown in 〈Table 4〉. Upon comparing pre-intervention and post-intervention muscle activities, there were no significant differences between the experimental and control group. Comparison within the groups is shown in 〈Table 4〉. Both groups show significant increases in all muscles ($p<.05$).

Comparison of Static Balance

Comparison of static balance between groups is shown in 〈Table 5〉. There were no significant differences between the groups. Comparison of static balance within groups is shown in 〈Table 5〉. There were no significant differences in static balance within the groups.

Table 3. General characteristics of the subjects

(Mean±SD)

	Experimental group (n=11)	Control group (n=10)	P
Height (cm)	167.90±8.11	166.78±12.18	.81
Weight (kg)	69.51±16.64	66.14±17.39	.66
BMI	23.70±5.85	23.47±3.92	.92

Table 4. Comparison of muscle activity. [mV]

	Group	Pre	Post	t	P
Tibialis anterior	Experimental group	213.36±25.17	268.33±23.40 †	−1.12	.28
	Control group	256.20±38.95	289.29±32.96 †		
Peroneus longus	Experimental group	119.30±23.42	190.83±30.05 †	−1.80	.09
	Control group	115.27±13.79	150.46±8.30 †		
Gastrocnemius	Experimental group	162.76±23.36	204.85±25.12 †	.21	.83
	Control group	188.71±30.49	233.87±34.94 †		

† Significant differences between pre-test and post-test.
*p<.05(=Significant differences between Experimental group and control group)

Table 5. Comparison of static balance ability. [cm²]

	Group	Pre	Post	t	P
Right foot	Experimental group	158.94±8.18	159.16±8.49	.29	.78
	Control group	164.80±8.43	162.98±8.83		
Left foot	Experimental group	156.78±7.50	159.64±7.30	.49	.63
	Group	161.48±8.95	162.90±9.16		

† Significant differences between pre-test and post-test.
*p<.05(=Significant differences between Experimental group and control group)

Comparison of Center of Gravity Motion

Comparison of center of gravity motion between groups is shown in 〈Table 6〉. There were no significant differences between the groups. Comparison of center of gravity motion within groups is shown in 〈Table 6〉. There were no significant differences in the center of gravity motion within the groups.

Table 6. Comparison of COM moving area [cm²]

Group	Pre	Post	t	P
Experimental group	974.81±163.49	672.90±75.15	−1.13	.27
Control group	700.78±102.59	606.36±118.96		

† Significant differences between pre-test and post-test.
*p<.05(=Significant differences between Experimental group and control group)

DISCUSSION

This study was university students in their 20s, who had ankle instability and who had performed stair exercises for 4 weeks. The control group performed the exercise with feet on the surface and the experimental group with heels off. The aim was to investigate the effect of the exercise on the activity of the muscle surrounding the ankle joint, as well as static balance. First, both groups showed a significant increase in the muscle activity of all three muscles. However, the experimental group showed more significant increases than the control group. Second, both groups did not show significant increases in static balance.

Andriacchi and Mikoz [30] reported that walking on stairs requires more leg strength and range of motion from the joints than walking on a flat surface. McFadyen and Winter [31] reported that whilst ascending stairs, the muscles that flex the knee joint and feet act as the main muscles. Chu et al. [32] stated that the muscles around the knee and ankle joints have a large role in maintaining balance, and Brown et al. [6] reported that weakness in the plantar flexion muscles made functional movements such as walking, bal–ance, and using stairs difficult.

Cho and Choi [17] showed that an increase in the flexion angle of the foot leads to an increase in the activity of leg muscles. Of the leg muscles, the tibialis anterior and gastrocnemius increase at a statistically similar rate at 20° through 30°. Choi et al. [33] per–formed closed kinetic chain exercises by standing upright and flexing the feet, which were effective in increasing balance ability. Shin [34] conducted a study applying leg muscle strengthening exercises where pre–intervention measurements of the outside leg were on average 27.87±6.74 (sec) and post–inter–vention was 41.46±12.04 (sec) which shows there was a significant difference in balance.

Consideration of the results of this study show that though there was a statistically significant increase in muscle activity post–intervention within the groups, performing the exercises with heels off was not more effective in increasing muscle activity than perform–ing the exercises with feet on the surface as all other measurements showed no significant changes. Furthermore, in contrast to previous studies, this study did not find an improvement in static balance which may suggest that there were external variables that affected the study.

Johnston et al. [35] reported that fatigue that is caused by over–exercising effects postural balance which results in increased swaying. James et al. (2002) reported that isokinetic plantar and dorsiflex–ion performed by young healthy adults had a signifi–cant effect on the range of posture control. Furthermore, Johnston et al. [36], using an isokinetic muscle strength measurement apparatus, evaluated balance ability after inducing muscle fatigue in the legs. It was shown that there was a reduction in bal–ance compared with before fatigue. With regard to these reports, this study did not allow sufficient rest between exercise sets and over–exercised the muscles surrounding the ankle joints by performing the exer–cise with heels off which may have led to muscle fatigue and therefore no significant change in static balance.

Limitations of this study pertain to the limited number of subjects participating in the study. Also, subjects were exclusively university students in their 20s with ankle instability and therefore the results of this study cannot be generalized. Furthermore, as individual characteristics, psychological states, daily routines, and other such personal aspects could not be regulated, there may have been variables that sig–nificantly affected the results. Lastly, as performing the exercise with heels off may result in a secondary injury, it is suggested that future studies thoroughly examine subjects for severity of ankle instability and exclude those that are likely to injure themselves. Improvements on such limitations, as well as further research, are necessary to ensure that use of stairs with heels off may be recommended as an interven–tion in the future for those with ankle instability.

CONCLUSION

This study aims to investigate the effect of going up and down the stairs with heels off for 4 weeks on the activity of the muscles surrounding the ankle joint and static balance ability in university students in their 20s with functional ankle instability. The study results showed that both groups experienced a sig–nificant increase in muscle activity in the tibialis anterior, peroneus longus, and gastrocnemius. As both groups showed a statistically significant increase, it would appear that exercising on the stairs with heels off does not largely affect the surrounding muscles of the ankle joint. Furthermore, there were no significant improvements in static balance which suggest that for future studies involving subjects with ankle instability, adjustments should be made to the exercise program before application.

REFERENCES

1. Bobath B. Adult hemiplegia: Evaluation and treatment. London. Medial Bools Ltd. 1990.
2. Jang JS, Lee SY, Lee MH, et al. The Correlations between Gait Speed and Muscle Activation or Foot Pressure in Stroke Patients. J Korean Soc Phys Ther. 2009;21(3):47–52.
3. Barker HB, Beynnon BD, Renstrop PA. Ankle injury risk factors in sports. Sport Med. 1997;23(2):69–74.
4. Lentell G, Baas B, Lopez D, et al. The contribu–tions of proprioceptive deficits, muscle function, and anatomic laxity to functional in stability of the ankle. J Orthop Sports Phys Ther. 1995;21(4):206–15.
5. Docherty CL, Valovich McLeod TC, Shultz SJ. Postural control deficits in participants with

functional ankle in stability as measured by the balance error scoring system. Sport Med. 2006;16(3):203–8.
6. Brown CN, Mynark R. Balance deficits in recreational athletes with chronic ankle in stability. J Athl Train. 2007;42(3):367–73.
7. Horak FB, Diener HC, Nashner LM. Influence of central set on human postural responses. J Neurophysiol. 1989;62(4):841–53.
8. Chae JB, Kim BJ, Bae SS. A study on the control factors of posture and balance. J Kor Phys Ther, 2001;13(2):421–31.
9. Kaminski TW, Hartsell HD. Factors Contributing to Chronic Ankle Instability: A Strength Perspective. J Athl Train. 2002;37(4):394–405.
10. Woflson L, Judge J, Whipple R, et al. Strength is a major factor in balance, gait, and the occurrence of falls. J Gerontol, A, Biol Sci Med Sci. 1995;50:64–7.
11. Tropp H. Pronator muscle weakness in functional instability of the ankle joint. Int J Sports Med. 1986;7(5):291–4.
12. Ebig M, Lephart SM, Burdett RC, et al. The effect of sudden inversion stress on EMG activity of the peroneal and tibialis anterior muscles in the chronically unstable ankle. J Orthop Sports Phys Ther. 1997;26(2):73–7.
13. Maclntyre NJ, Rombough R, Brouwer B. Relationships between calf muscle density and muscle strength, mobility and bone status in the stroke survivors with subacute and chronic lower limb hemiparesis. J Musculoskelet Neuronal interact. 2010;10(4):249–55.
14. Dorsch S, Ada L, Canning CG, et al. The strength of the ankle dorsiflexors has a significant contribution to walking speed in people who can walk independently after stroke: an observational study. Arch Phys Med Rehabil. 2012;93(6):1072–6.
15. Gefen A. Biomechanical analysis of fatigue related foot injury mechanisms in athletes and recruits during intensive marching. Medical & Biological Engineering & Computing. 2002;40(3):302–10.
16. Winter DA, Prince F, Frank JS, Powell C, et al. Unified theory regarding A/P and M/L balance in quiet stance. J Neurophysiol. 1996;75:2334–43
17. Cho YH, Choi JH. Muscle Activities of the Lower Extremity based on Ankle Plantar–flexion in Elderly Women. J Kor Phys Ther. 2009;21(4):57–63.
18. Jeon HM, Park SK. The Effect of Stair Ascending Speed on Foot Pressure and Lower Extremity Muscle Activation Patterns. The Korean Journal of Sport. 2013;11(1):239–49.
19. Seo KC, Jang EJ. The Effect of Gait Ability in the Stroke Patients after Lamp Gait Exercise and Stair Gait Exercise by Proprioceptive Neuromuscular Facilitation Techniques. Journal of Special Education & Rehabilitation Science. 2013;52(3):127–44.
20. Flynn J. Kinematical variability of normal climbing and descending stairs. University of Nashville, TN. Master's Thesis. 1977.
21. Mercer VS, Sahrmann SA. Postural Synergies Associated With a Stepping Task. Phys Ther. 1999;79(12):1142–52.
22. Lee SC, Kim TH, Cynn HS, et al. The Influence of Unstability of Supporting Surface on Trunk and Lower Extremity Muscle Activities During Bridging Exercise Combined With Core–Stabilization Exercise. Phys Ther Korea. 2010;17(1):17–25
23. Lim SW, Kim SH, Kim YN, et al. The Effect of Balance Training on Balance Ability and Ankle Joint Muscle Activity. Journal of the Korean Academy of Clinical Electrophysiology. 2010;8(2):13–8.
24. Park CB, Kim YN, Kim YS, et al. Effect of Inflatable Standing Surface With Different Levels of Air Pressure on Leg Muscle Activity. Phys Ther Kor. 2013;20(2):1–10.
25. Hertel J, Earl JE, Tsang KK, et al. Combining isometric knee extension exercises with hip adduction or abduction does not increase quadriceps EMG activity. Br J Sports Med. 2013;38(2):210–3.
26. Nam HJ, Lee JH. The Effects of Modified Straight Leg Raise Exercise on Balance Activity and Electromyography Muscles Activation of lower limbs muscle. The Korea Journal of Sports Science. 2016;25(3):1297–308.
27. Jun JY, Park MC. The Effect of Stair Exercise with Restriction Blood Flow on Knee Extensor Muscle, J Korean Soc Phys Med. 2015;10(4):9–14.
28. Kim YH. The Effects of Task Oriented Stair Gait Training on Muscle Activities of the Lower Extremity and Balance in Stroke Patients. Master's Degree. Yongin University. 2017..
29. Perry, J. Gait Analysis, Normal and pathological function, NewYork: Slack Inc. 1992.
30. Andriacchi TP, Mikoz RP. Musculoskeletal dynamics, locomotion and clinical applications, In: Basic Orthopaedic Biomechanics. New York. Raven Press. 1991;21–92.
31. McFadyen BJ, Winter DA. An intergrated biomechanical analysis of normal stair ascent and descent. J Biomech. 1988;21(9).:733–44.

32. Chu LW, Pei CK, Chiu A, et al. Risk factor for falls in hospitalized older medical patients. The J Gerontol. 1999;54:38-43.
33. Choi WJ, Jo EM, Chun JW, et al. The Effects of Ankle Plantar flexion exercise and Stepper on the Balance Ability in Normal peoples. J of Korea Proprioceptive Neuromuscular Facilitation Association. 2009;7(3):7-16.
34. Shin, Chul - Ho. Effect of Exercises to Develope Muscular Strength Legs of Aged People to Maintaince the Sense of Balance. Journal of the Korea Walking Science Association. 2006;6; 131-8.
35. Johnston RB, Howard ME, Cawley PW, et al. Effect of lower extremity muscular fatigue on motor control performance. Med Sci Sports Exerc. 1998;30(12):1703-7.
36. James A, Stephan J. Effects of isokinetic ankle fatigue on the maintenance of balance and postural limits. Arch Phys Med Rehabil. 2002;83:224-8.