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Original Article

Effects of underwater treadmill walking training on the peak torque of the knee in hemiplegic patients

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Abstract. [Purpose] This study investigated the effects of underwater treadmill walking training on the peak torque of the knee in hemiplegic patients. [Subjects and Methods] Thirty-two subjects, who were randomly allocated to an experimental group (*n*=16) and a control group (*n*=16), performed underwater treadmill walking training and overground treadmill walking training, respectively, for 30 minutes/session, 3 sessions/week, for 6 weeks. An isokinetic dynamometer was used to assess the peak torque. [Results] The subjects in the experimental group showed an increase in the peak knee extension torque compared to the control group. [Conclusion] The results suggested that underwater treadmill walking training has a greater effect on peak knee extension torque at velocities of 60°/sec and 120°/sec than overground treadmill walking training.
Key words: Knee joint, Stroke, Underwater treadmill

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INTRODUCTION

Walking disorders, which constitute one of the major problems in hemiplegic patients, are a result of weakness of the affected side of the body[1)] and the relatively posterior location of the center of gravity, which limits their movements and reduces the risk of falls[2)]. Treadmill walking is well known as an effective intervention for increasing walking ability, stability of the lower extremity, muscle strength, balance, and re-recognition of motor control required for the walking pattern[3)]. Underwater therapy helps improve physical functioning for a better quality of life by utilizing the properties of water. Hydrostatic pressure, buoyancy, friction, and viscous resistance are important water properties, and underwater resistance, in particular, is 12 times greater than overground resistance. Additionally, water resistance is changeable depending on the velocity of body movement. Faster movement of the body is associated with greater resistance[4)]. Exercising in water helps achieve an acquired symmetrical gait and limits unnecessary movement, thereby affecting not only energy efficiency but also muscle strength and endurance[5)]. Recently, a few studies investigated the effects of treadmill exercise in restricted water depth on improvement of muscle strength and gait velocity. Moreover, previous studies have proved that underwater treadmill walking training (UTWT) is beneficial for weight bearing in the stance phase, which improves both gait and postural control in patients with hemiplegia[6)]. Several studies have been conducted on the effects of UTWT on balance and gait. However, a quantitative evaluation of isokinetic muscle strength in hemiplegic patients has not been studied sufficiently. Therefore, the purpose of this study was to compare the effects of UTWT and those of overground treadmill walking training (OTWT) on peak knee flexion and extension torques.

SUBJECTS AND METHODS

This study was performed at the C hospital in Daejeon. Thirty-two subjects with hemiplegia of ≤1 year onset participated in the study. The subjects were allocated randomly to an experimental group (EG) (*n*=16) and a control group (CG) (*n*=16). The general characteristics of the subjects are shown in Table 1.

There were no significant differences in homogeneity of the subjects in general characteristics. The inclusion criteria were as follows: Mini-mental state examination-Korea score >24 points; able to walk independently for 20 minutes; and no history of orthopedic or neurologic problems other than a stroke. All subjects provided written informed consent for participation in the study prior to its initiation. This study followed the principles of the Declaration of Helsinki. The patients participated in the training for 30 minutes/session, 3 sessions/week, for 6 weeks, from November 3

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Table 1. General characteristics of the subjects (N=32)

	EG (n=16)	CG (n=16)
Age (years)	50.9 (9.9)	49.3 (10.7)
Weight (kg)	62.5 (11.0)	63.5 (9.1)
Height (cm)	165.4 (6.9)	166.9 (5.2)
Gender (male/female)	11/5	10/6
Affected side (right/left)	7/9	5/11
Lesion (infarction/hemorrhage)	10/6	9/7
Period since the onset of stroke (months)	7.9 (2.5)	8.0 (2.4)

Values are presented as mean (standard deviation); EG: experimental group (Underwater treadmill walking training); CG: control group (Overground treadmill walking training)

Table 2. Comparison of the peak knee extension and flexion torques at each angular velocity (N = 32)

			EG (n=16)	CG (n=16)
60°/sec	Extension	Pre-test	49.4 (21.4)	47.2 (16.9)
		Post-test	73.9 (21.6) ^{a**}	57.7 (16.6) ^{a*,b**}
	Flexion	Pre-test	42.6 (21.5)	38.1 (14.1)
		Post-test	52.8 (17.4)^{a*}	45.9 (13.5) ^{a*}
120°/sec	Extension	Pre-test	31.0 (14.6)	30.8 (9.8)
		Post-test	50.3 (20.8) ^{a**}	39.0 (10.0) $^{a*, b**}$
	Flexion	Pre-test	24.8 (11.6)	26.5 (13.6)
		Post-test	33.3 (10.0) ^{a*}	30.4 (13.7)

Values are presented as mean (standard deviation); *p<0.05; **p<0.01; EG: experimental group; CG: control group; Unit: Nm; ^{a}, in group; ^{b}, between groups

to December 12, 2014. Warm-up exercises were performed for 5 minutes to induce muscle relaxation, and these were followed by UTWT for 20 minutes, and cool-down exercises and stretching for the final 5 minutes to reduce muscle fatigue. HYDRO PHYSIO (Syspal Limited, England), an underwater treadmill, was used at a velocity that was 36% of the overground gait speed at the start, and the velocity was gradually increased by 0.1 m/s until the subjects were walking as fast as possible[7]. The subjects wore aqua shoes for safety. Water temperature and depth were 34 °C and up to the xiphoid process, respectively[6]. RTM 500 (BIODEX, USA), an overground treadmill, was used following the same procedure as the UTWT. The Isokinetic Dynamometer (BIODEX, USA) was used to assess knee extension peak torque (KEPT) and knee flexion peak torque (KFPT). The subjects were instructed to stand holding a chair, with the thigh and ankle on the test side fixed by a stabilization strap. The maximum torque was assessed 3 times at 60 and 120°/sec and the highest torque among these was selected. A 30-second rest was given between tests. This test tool has high test-retest reliability (r=0.81) and validity (r=0.99)[8]. All data were analyzed using SPSS version 12 (Statistical Package for the Social Science). The Shapiro-Wilk test was used for a normal distribution. All data are presented as mean (standard deviation). The Pearson χ^2 and independent t-tests were used for homogeneity of subject characteristics. The paired t-test and independent t-test were used to compare pre- and post-test values in each group and the differences between both groups, respectively. A significance level of $\alpha=0.05$ was used for all statistical tests.

RESULTS

Table 1 presents the pre- and post-UTWT and OTWT results. There were significant differences post-intervention in the KEPT and KFPT at the angular velocity of 60°/sec in both the EG and CG. Moreover, there was a significant difference between the groups. There were significant differences post-intervention in the KEPT at the angular velocity of 120 °/sec in both the EG and CG. Additionally, there was a significant difference between the groups. There was a significant difference post-intervention in the KFPT at the angular velocity of 120°/sec in the EG (Table 2).

DISCUSSION

The knee joint plays an important role during participation in exercises and activities of daily living. The peak torque can be useful data in assessing a subject's exercise ability[9]. In this study, there was no significant difference in the KFPT at the angular velocity of 120°/sec in the CG. However, there was a significant difference in the KEPT at the angular velocity of 120°/sec in the CG. In addition, there were significant differences in the KFPT and KEPT at the angular velocity of 60°/sec in both the EG and CG. In previous studies, OTWT for 12 weeks improved overall lower extremity strength in hemiplegic patients[10], and treadmill walking training applied in 10 hemiplegic patients for 12 weeks positively affected the isokinetic muscle strength in the paralyzed knee joint[11]. Therefore, UTWT is beneficial for improving both muscle strength and recovery from paralysis. There were significant differences in the KEPT and KFPT at all angular velocities after the UTWT. In previous studies, UTWT has been shown to improve lower extremity muscle strength, which improved walking velocity, cadence[6], and muscle endurance[4] in the elderly. Moreover, there was no significant difference in the KFPT at all angular velocities in both groups, but the EG group showed significant improvement in the KEPT compared to the CG. A previous study reported that UTWT applied in 10 elderly people influenced activation of gluteus maximus, tensor fascia latae, and biceps femoris in the stance phase[12] and improved hip flexor strength, as a result of which, there was improvement in gait velocity and stride[7]. However, the reason for a significant difference in the KEPT but not in the KFPT was that underwater exercise influences muscle strength more than overground exercise owing to water resistance, which was proved in the previous study. According to Han's study, knee extension during the swing phase in UTWT is performed against much more water resistance, resulting in increased muscle strength[13]. In addition, previous studies have reported that muscle contraction in the quadriceps femoris during UTWT was higher than that during OTWT[14], and the anteroposterior postural perturbation of static postural control in the UTWT group showed a considerable difference, decreasing by 41% compared to that before training[15]. The limitations of this study were a small sample size, lack of a follow-up test to determine the carry-over effects, and no constraint of the effects of other joints. Further investigation of the effects of an underwater therapy program in hemiplegic subjects with modifications to address the above-mentioned limitations is needed.

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