

Original Article

# The Training and Detraining Effects of 8 Weeks of Water Exercise on Obstacle Avoidance in Gait by the Elderly

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**Abstract.** [Purpose] This study aimed to provide useful information for fall prevention for the elderly by investigating how safely the elderly cross an obstacle after 8 weeks water exercise, and how much of the training effect remained 8 weeks after finishing the exercise. [Subjects] Eleven elderly participants participated in this study. [Methods] To identify the training and detraining effect of 8 weeks of water exercise, a 3-D motion analysis with 7 infrared cameras and one force plate, was performed. [Results] In most of all variables, statistically significant training and detraining effects at obstacle heights of 30% leg length were found. At obstacle heights of 40% leg length, statistically significant training effects were found but only improvement pattern of detraining effects were found for all variables. [Conclusion] The findings of this study indicate that 8 weeks of water exercise at the level of RPE 12–13 may help the elderly to safely cross obstacles at the most common height associated with falls (30% of leg length) for at least 8 weeks after training termination. The training effect, however, should not be expected to last for 8 weeks after the training at obstacle heights of 40% height of their leg length, which is a more difficult height for the elderly to cross.

**Key words:** Detraining effect, Training effect, Elderly fall

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## INTRODUCTION

Many countries are becoming increasingly aware of various injuries of the elderly whose proportion of entire population is rapidly increasing worldwide. In particular, falls are caused by weakened lower limb muscle strength and reduced balance ability, and are the most frequently experienced accident by the elderly. In addition, falls ranked the second and third for the elderly injuries, unlike for younger people<sup>1, 2)</sup>. Therefore, many researchers have been interested in ways of reducing falls by the elderly fall. Previous studies have reported that continuous exercise can improve the lower limb muscular strength and balance of the elderly reducing their chances of fall<sup>3–5)</sup>. The exercises researchers have studied can be largely divided into land exercises such as walking, tai chi, and lower limb exercise, and aquatic exercises in which these exercises are performed in water with support from buoyancy. Land exercises may have better effects because buoyancy counteracting gravity is absent, but they are reported to be more likely to cause injuries to the elderly who have weak physical strength<sup>6, 7)</sup>. Although there

is risk of injuries depending on the training method, it has been proven and reported by many researchers that continuous exercise by the elderly can reduce their risk of falls and improve their health.

The major external fall risk factors for the elderly include the environment when walking, loss of balance, and obstacles on the ground. Among them obstacles on the ground are reported to be the most common cause of falls<sup>8)</sup>. Therefore, to better understand the mechanisms of falls by the elderly, many researchers have reproduced the characteristics of common obstacles such as door sills, bathroom thresholds, stairs, pathways, and parking bumps for research into falls by the elderly. Chen et al.<sup>9)</sup> set the heights of obstacles to 2.5 cm, 5.2 cm and 15.2 cm, which are common heights of bathroom thresholds, road bumps, and toys, in their research, while Austin et al.<sup>10)</sup> set them at 31 mm and 126 mm, which are common heights of doorsills, curbs, or parking bumps, and the median height of the two, 76 mm. Other researchers have used obstacle heights proportional to subjects' leg lengths to reduce effects related to subjects' height<sup>11–17)</sup>.

The obstacles that can cause falls by the elderly in day-to-day life have a common characteristic: the elderly inevitably have to cross them. It would be ideal if the elderly could avoid such situations but this is not a feasible solution. Therefore, to measure the risk of falls by the elderly, due to obstacle-crossing, it seems more practical to evaluate how the elderly overcome obstacles instead of indirectly as-

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**Table 1.** Aquatic exercise program (weeks 1–4)

	Program	Duration
Warm-up	Stretching	10 min
	Side walking	5 min
	Forward walking	12 min
Main exercise	Jogging	1 min
	Backward walking	12 min
	Cross stepping	5 min
	Forward-backward walking with hip joint rotation	5 min
Cool-down	Static balance exercise	5 min
	Stretching	5 min

sessing improvement of muscular strength due to training. Although many training studies have been conducted on reducing falls by the elderly, from the perspective of the elderly who are supposed to accept and use such information, additional information such as maintenance of training effect (detraining effect) is necessary. In other words, although the fact that continuous exercise reduces the risk of fall is very important information for the elderly, the detraining effect in terms of how long the effect of such exercise lasts is more important to them for preventing falls. However, little research has been performed on the detraining effect despite its importance. In general, the detraining effect usually defined simply such as the reduction of muscle strength after suspension of exercise. This type of information does not seem to be clear enough for the elderly to understand how much they are exposed to the risk of fall. Therefore, clearly understanding the detraining effect is, along with continuous training, very important information for the elderly to prevent falls.

Most of previous research on detraining effects has so far used indirect methods, and has concluded that muscular strength is reduced somewhat after the suspension of training<sup>18–20</sup>. These indirect methods do not provide clear and direct information for the elderly regarding the use of these findings. In other words, it seems insufficient to use indirect methods, such as simple reduction of muscular strength. Rather, we should be expressing what types of movements the elderly should make in the environments where they frequently experience falls.

In a previous study, we investigated how 8 weeks of aquatic exercise influences prevention of falls<sup>21</sup>. However, that study was limited to gait stability (i.e. inclination angles) during obstacle gait and failed to examine how long the training effect lasted. Furthermore, our previous study did not reveal the relationship between obstacle heights and the swing foot which approaches the obstacle. Therefore, the purpose of this was to provide useful information for fall prevention for the elderly by investigating how safely the elderly cross an obstacle after 8 weeks water exercise, and how much of the training effect remained 8 weeks after finishing the exercise.

## SUBJECTS AND METHODS

The subjects of this study were the same as those who

**Table 2.** Aquatic exercise program (weeks 5–8)

	Program	Duration
Warm-up	Stretching & walking	10 min
	Side running	5 min
	Forward running	12 min
Main exercise	Walking	1 min
	Backward running	12 min
	Cross step running	5 min
	Fast forward walking	5 min
Cool-down	Static balance exercise	5 min
	Stretching	5 min

participated in the previous study conducted by the author and colleagues<sup>21</sup>. After termination of the aquatic training, the purpose of the study regarding the detraining effect was explained to the research subjects. The subjects did not perform further exercise for 8 weeks after termination of the training, and they were asked to contact the author if they participated in any exercise other than usual. None of the research subjects participated in any continuous exercise other than natural exercise in daily life, and this fact was re-confirmed to the author before starting final test. This study was approved by the Institutional Review Board of Korea National Sport University and prior to their participation, informed consent was received from each subject.

The aquatic exercise program used in this study was conducted by a qualified trainer, three times a week, 60 minutes per session for 8 weeks. The exercise was composed of warm-up, cool-down, and main exercise. Also, different exercises were applied to the subject according to increase of the period. The details are provided in Tables 1 and 2.

In order to investigate the training and detraining effect of the 8 weeks of water exercise, the subjects performed three obstacle-crossing walks (a week before the beginning of water exercise, 1 week after termination of the exercise, and 8 weeks after termination of the exercise). Before each test, the subjects were explained about the procedure of the test, and during the test they performed enough exercise in order to induce most natural movements. The test procedure and settings of this study were the same as those of the previous study<sup>21</sup>. In order to evaluate the detraining effect more accurately, the obstacle heights were set at 30% and

**Table 3.** COP distances for MaxCOP and MeanCOP of the training periods

Obstacle height (% of leg length)	MaxCOP (mm)		MeanCOP (mm)	
	30%	40%	30%	40%
Before-training	215.9 ± 27.0**	126.7 ± 26.1*	52.8 ± 4.9**	39.3 ± 4.1
After-training	91.5 ± 17.8	67.4 ± 5.5	35.1 ± 5.7	30.6 ± 2.5
De-training	97.3 ± 23.5	113.5 ± 23.6	39.6 ± 4.0	42.9 ± 6.1

Values are group mean ± standard error. \*\*: a significant difference with before training. \*: a significant difference between before and after aquatic training ( $p < 0.05$ ).

**Table 4.** Clearance distances of obstacle avoidance parameters of the training periods (Unit: cm)

Obstacle height (% of leg length)	TC		HC		MVHC	
	30%	40%	30%	40%	30%	40%
Before-training	24.1 ± 1.9	23.6 ± 1.4	72.1 ± 3.6	82.7 ± 4.5	15.4 ± 1.2	14.8 ± 2.7
After-training	31.8 ± 1.8	31.4 ± 1.8	88.9 ± 3.9	87.7 ± 2.1	19.4 ± 1.5	18.5 ± 3.7
De-training	31.8 ± 2.2	26.6 ± 1.8	83.4 ± 4.1	86.5 ± 4.5	16.7 ± 1.6	16.2 ± 4.5

Values are group mean ± standard error. \*\*: a significant difference with before training. \*: a significant difference between before and after aquatic training ( $p < 0.05$ ).

40% of subjects' leg lengths, which have been reported as comfortable and more difficult heights to cross<sup>16, 17</sup>).

Two variables of gait stability and four variables of obstacle-crossing were used to evaluate the risk of fall for the elderly during obstacle-crossing. The gait stability variables used in this study were maximum center of pressure (MaxCOP) and mean center of pressure (MeanCOP). MaxCOP is the maximum distance from average COP to the COP at any instant during stance phase, and MeanCOP is the mean distance between average COP and COP at each instance during stance phase. In general, change in COP distance during the stance phase is representative of gait stability. The longer and shorter distances of COP suggest that subject is in unstable and stable situation, respectively during stance phases. The variables of obstacle-crossing used in this study were Toe Clearance (TC), Heel Clearance (HC), and Maximum Vertical Heel Clearance (MVHC). These variables are well known as indicators of obstacle-crossing stability and we follow the definitions of them given by of Chen and Lu<sup>13</sup>.

To verify the effect of the training and detraining effects, a repeated one-way ANOVA was performed. In addition, when there was a significant difference among the periods, the Bonferroni post-hoc was performed. In this study, statistical significance was set at  $\alpha = 0.05$ .

## RESULTS

The results of obstacle clearance parameters and gait stability parameters among training periods are presented in Tables 3 and 4. For most of the variables, statistically significant training and detraining effects were found for obstacle heights of 30% leg length (Table 3 and 4,  $p < 0.05$ ). However, for obstacle heights of 40% leg length, statistically significant training effects were found for most of the variables (Tables 3 and 4,  $p < 0.05$ ), but only improvement pattern of detraining effects were shown for all the variables (Tables 3 and 4).

## DISCUSSION

The main purpose of this study was to examine how safely the elderly cross an obstacle after an 8 weeks of aquatic training, and how much of the training effect remained 8 weeks after finishing the training. For the evaluation, variables that representative of gait stability and obstacle-crossing stability were investigated, and we attempted to verify the detraining effect by using for obstacle heights of 30% leg length, which is comfortable for the elderly to cross, and 40% leg length, which is more difficult to cross.

In this study, MaxCOP and MeanCOP, which were evaluated to investigate the stability of the supporting foot when the elderly subjects crossed obstacles, showed statistically significant training effects at both the obstacle heights of 30% and 40% leg lengths (Table 3). However, at obstacle heights of 30% leg length, which is known as a comfortable obstacle height for the elderly to cross, the training effect was maintained at 8 weeks after ending the exercise, but not at the obstacle heights of 40% leg length. This finding indicates that, although the 8 weeks aquatic exercise helped the elderly to safely cross an obstacle with a height of 30% leg length with the stable support of the supporting foot, it was not effective at maintaining the training effect in crossing obstacles with a height of 40% leg length, a height that requires better balance ability and muscular strength than at the 30% leg length obstacle height. This results seems to be related the intensity or period of the exercise used in this study. Therefore, to verify this result, future research will need to investigate exercise over a longer period, such as 16 and 24 weeks, and training intensities, other than the RPE12–13 used in this study.

For the variables of obstacle-crossing, significant training effects were found for all the variables at both obstacle heights, except HC at the obstacle height of 40% leg length (Table 4,  $p < 0.05$ ). However, in terms of the detraining effect after 8 weeks, only TC at the obstacle height of 30% leg length showed a statistically significant difference (Table

4,  $p < 0.05$ ). TC and HC are variables representing the safe distances before and after crossing an obstacle, and are reported to be closely related to safe obstacle-crossing<sup>9, 17</sup>. In the case of TC, although the distance after the training increased at both the 30% and 40% leg length obstacle heights (30%: 24.12 cm < 31.38 cm, 40%: 23.55 cm < 31.40 cm), 8 weeks after termination of the training, the effect was maintained the obstacle height of 30% leg length, and the obstacle height of 40% leg length, it decreased to almost the same level as before training (31.76 cm and 26.60 cm at obstacle heights of 30% and 40% leg length, respectively).

MVHC occurs at the most unstable moment when crossing an obstacle. At this moment, only one foot is supporting the entire body and the crossing foot is at the highest position above the ground, which requires maximum muscular strength for stability. Even though MVHC showed statistically significant increases at both obstacle heights as a result of the 8 weeks aquatic training, it had decreased to almost the same level as before training at 8 weeks after the suspension of training (30%: 15.38 cm → 19.39 cm → 16.72 cm, 40%: 14.79 cm → 18.52 cm → 16.19 cm). Similar to the results of the gait stability parameters, the reason for this detraining effect seems to be related to either the intensity or period of the exercise used in this study.

The findings of this study indicate that 8 weeks of aquatic exercise at the level of RPE 12–13 may help the elderly safely cross obstacles at the most common height (30% leg length) related to falls for at least 8 weeks after the termination of training. The training effect, however, should not be expected to last for 8 weeks after training at obstacle heights of 40% of their leg length, which is a more difficult height for the elderly to cross. To supplement these findings, further research into the intensity or the duration of exercise needed to maintain the training effect is required.

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