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The Effects of Augmented Reality-based Otago Exercise on Balance, Gait, and Falls Efficacy of Elderly Women

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Abstract. [Purpose] The purpose of this study was to determine the effects of augmented reality-based Otago exercise on balance, gait, and falls efficacy of elderly women. [Subjects] The subjects were 21 elderly women, who were randomly divided into two groups: an augmented reality-based Otago exercise group of 10 subjects and an Otago exercise group of 11 subjects. [Methods] All subjects were evaluated for balance (Berg Balance Scale, BBS), gait parameters (velocity, cadence, step length, and stride length), and falls efficacy. Within 12 weeks, Otago exercise for muscle strengthening and balance training was conducted three times, for a period of 60 minutes each, and subjects in the experimental group performed augmented reality-based Otago exercise. [Results] Following intervention, the augmented reality-based Otago exercise group showed significant increases in BBS, velocity, cadence, step length (right side), stride length (right side and left side) and falls efficacy. [Conclusion] The results of this study suggest the feasibility and suitability of this augmented reality-based Otago exercise for elderly women.
Key words: Augmented reality, Otago exercise, Falls efficacy

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INTRODUCTION

Falls occur more often in women than in men, and the rate of falls in people older than 65 years is greater than 33%[1)]. Falls are affected by many causes; for example, culture, sex, social services regarding health, physical activities, healthy intake, drug intake, behavior that increases dangerous causes, attitudes, fear of falls, treatment after falls, and personal factors, like race, social environment, and economic strength, are factors affecting personal life and are taken as having a negative effect on quality of life[2)]. However, these fall factors can be good prevention factors that decrease

danger of falls in the elderly[3–5)]. Loss of muscle strength in the weak elderly occurs more on the upper part of the body than the lower part; special knee supporting muscle strength shows a decrease, so that the body sways even when standing with two feet supported on a bearing surface[6)]. In addition, gait is also affected, so that decrease in step length, stride length, gait speed, and toe off and double support time increase. Therefore, elderly persons should increase muscle and maintain balance, and prevent falls through experimental factors like exercise[7)].

Research on fall prevention exercise for the elderly has been proposed, which includes balancing exercise while standing on a hard and soft surface[8)], resistive exercise that increases muscle strengthening exercise using a Theraband[9)], endurance exercise riding on a stationary exercise bike[10)], and maintenance of a maintain static body posture that can improve flexibility, like yoga[11)] and t'ai chi ch'uan, which is effective for balance and motor sensation[12)]. However, all these studies suggest different methods, and there is no typical method.

The Otago exercise program is composed of muscle strengthening, balance training, and walking, which suggests a specific training method[13)]; in an experiment using this training program, males and females aged older than 70 were randomly divided into an experimental group and control group; the results showed an increase in balance, muscle strength, and falls percentage, and the danger rate of falls was decreased[14)].

On the other hand, recent rehabilitation research has introduced a new rehabilitation training method using various forms of tasks that fit the patient's personal purpose and is performed using virtual reality and augmented reality; the results showed significant functional improvement[15, 16)]. Augmented reality provides reality and additional information using external projection equipment[17)] combined with an imagine target, which turn increases the reality effects, which increases feedback, making flexible imagined changes become reality and vice versa[18)]. Therefore, the treatment environment when using augmented reality increases task complication gradually and also helps in increasing the effects of the education[19)].

Thus, this study was conducted in order to investigate the effect of application of augmented reality-based Otago exercise on the elderly for fall prevention and to provide basal information.

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SUBJECTS AND METHODS

A total of 21 elderly women who voluntarily agreed to active participation were included in this study. The selection criteria were sufficient cognitive ability to participate, as indicated by a mini-mental state examination score of 24 or higher. The exclusion criteria were 1) disabilities in visual, auditory sensation, and vestibular organs; 2) defects in extremities; and 3) fracture in the past year. All of the subjects received an explanation of this study and agreed to participate. A total of 21 elderly women were selected and divided into an augmented reality-based Otago exercise group, which included 10 subjects, and an Otago exercise group, which included 11 subjects; exercise was performed for 12 weeks. General characteristics of the augmented reality-based Otago exercise group and Otago exercise group are shown in Table 1.

This study was conducted in order to provide an augmented reality environment for training of elderly women, provide the graphic and vision-based web-camera recognition handling technique, provide the vision and auditory expression technique for emotional feedback, build up vision and auditory models and a recognition information database, and provide a handling technique for situational perception and its reactions as a way of improving balance, gait, and physical factors in falls; in particular, real-time motion recognition was performed using a preserved modeled movement for measurement of speed of the movement and its accuracy. The first week of research started with a moderate intensity exercise program that subjects could perform five times. Subjects stood in front of a computer with a web camera, which had an SVGA resolution (800 × 600) head-mounted display (i-visor FX601, Dae-Yang E&C Co, Korea, 2008) and followed the movement displayed. The computer sensed the movement of the subjects and sent the information to the head-mounted display in order to repeat the task and move to the next level, which increased the speed.

Otago exercise was developed at Otago Medical School to prevent falls in the elderly[13]. The muscle strengthening exercises include knee extension exercise for front knee strengthening, knee flexion for back knee strengthening, hip joint abduction for side hip strengthening, plantar flexion for calf raises of the ankle, and dorsiflexion for toe raises of the ankle; the balance training includes backward walking, walking and turning around, heel to toe walking, one leg stand, heel walking, toe walk, heel to toe walking backward, sit to stand, and stair walking. Muscle training and balance training are performed for a period of 40 minutes each, three times per week, according to the level of the subjects, and after the exercise, there was a 10-minute cooling down period[13].

Balance ability was measured using the Berg Balance Scale (BBS). The BBS is a valid and reliable instrument for measuring both the static and dynamic aspects of balance in elderly people with stroke[20]. BBS scores range from 0 to 56 points, and the higher the score, the better the balance.

Gait function was measured using a GAITRite system (GAITRite, CIR systems Inc., Havertown, PA, USA). The GAITRite system was used to measure spatiotemporal parameters, including gait velocity, cadence, step length, and stride length. Subjects were asked to walk at a comfortable speed, without the use of an assistive device, along a 10 m hallway[21].

Table 1. Characteristics of the participants (N=21)

	VR based Otago exercise group (n=10)	Otago exercise group (n=11)
Age (y)	72.90 (3.41) [a]	75.64 (5.57)
Height (cm)	151.08 (3.31)	151.80 (9.74)
Weight (kg)	57.51 (4.87)	57.36 (8.73)
BMI (kg/m^2)	25.20 (2.02)	24.82 (2.11)

[a] mean (SD). BMI, Body Mass Index

Fall efficacy was measured using the short Falls Efficacy Scale-International (FES-I) version, which is a tool for measuring confidence regarding prevention of falls. Kempen et al.[22] selected seven items for the Short FES-I out of the 16 items of the FES-I. The original questionnaire contains 16 items scored on a four-point scale. Lower scores indicate higher confidence in prevention of falls[23].

The SPSS statistical package, version 18.0, was used in performance of all statistical analyses. The dependent variables were balance test, gait function and falls efficacy test. General characteristics of the subjects and variables followed a normal distribution. The paired t-test was used to determine changes between before and after the balance test, gait function, and falls efficacy test. The independent t-test was used for analysis of changes between groups of dependent variables. Results were considered significant at $p<0.05$.

RESULTS

Differences in balance, gait, and falls efficacy after training are shown in Table 2. The BBS score showed a significant increase, from a score of 47.60±5.36 before to a score of 53.70±2.50 (p=0.000) after in the augmented reality-based Otago exercise group; a significant difference, from a score of 48.91±4.53 to a score of 52.45±2.91, was observed in the Otago exercise group (p=0.001).

Gait parameters in the augmented reality-based Otago exercise group showed significantly increased gait velocity (from 79.83±13.22 cm/s to 99.18±11.56 cm/s, p=0.001), cadence (from 100.79±9.92 steps/min to 116.73±8.81 steps/min, p=0.000), left side stride length (from 93.88±10.18 cm to 100.25±9.91 cm, p=0.041), right side step length (from 46.78±4.67 cm to 50.55±5.13 cm, p=0.011), and right side stride length (from 93.64±10.48 cm to 100.39±10.07 cm, p=0.019). The Otago exercise group showed significantly increased gait velocity (from 90.22±12.22 cm/s to 103.76±12.83 cm/s, p=.001), cadence (from 107.92±8.69 steps/min to 118.55±7.67 steps/min, p=0.022), left side step length (from 51.12±5.68 cm to 53.43±6.84 cm, p=0.023), and right side stride length (from 100.64±12.79 cm to 105.05±14.02 cm, p=0.028).

Table 2. Comparison of balance, gait and fall efficacy within groups and between groups (N=21)

Parameters	Values				Change values	
	VR-based Otago exercise (n=10)		Otago exercise (n=11)		VR based Otago exercise (n=10)	Otago exercise (n=11)
	Before	After	Before	After	After - Before	After - Before
Balance parameters						
BBS (score)	47.60 (5.36) [a]	53.70 (2.50) ***	48.91 (4.53)	52.45 (2.91) **	6.61 (3.41)	3.55 (2.66)
Gait parameters						
Velocity(cm/s)	79.83 (13.22)	99.18 (11.56) **	90.22 (12.22)	103.76 (12.83) **	19.35 (13.24)	13.55 (9.97)
Cadence (steps/min)	100.79 (9.92)	116.73 (8.81) ***	107.92 (8.69)	118.55 (7.67) *	15.94 (8.79)	10.64 (12.97)
Left side						
Step length (cm)	46.35 (5.75)	49.61 (5.40)	51.12 (5.68)	53.43 (6.84) *	3.26 (5.17)	2.31 (2.86)
Stride length (cm)	93.88 (10.18)	100.25 (9.91) *	100.49 (12.47)	104.59 (14.11)	6.38 (8.45)	4.11 (6.49)
Right side						
Step length (cm)	46.78 (4.67)	50.55 (5.13) *	48.94 (7.31)	51.30 (7.69)	3.77 (3.72)	2.35 (3.64)
Stride length (cm)	93.64 (10.48)	100.39 (10.07) *	100.64 (12.79)	105.05 (14.02) *	6.74 (9.26)	4.41 (5.70)
Falls Efficacy (score)	14.50 (4.58)	11.80 (3.71) *	12.36 (6.23)	11.18 (4.53)	−2.70 (2.98)	−1.18 (5.23)

[a] mean (SD). BBS, Berg Balance. * $p<0.05$; ** $p<0.01$; *** $p<0.001$

The falls efficacy score for the augmented reality-based Otago exercise group showed a significant difference, from a score of 14.50±4.58 to a score of 11.80±3.71 (p=0.019); however, the Otago exercise group showed no significant difference (from a score of 12.36±6.23 before to a score of 11.18±4.53 after).

DISCUSSION

This study examined the effect of augmented reality-based Otago exercise on balance, gait functions, and falls efficacy of elderly women. As one grows older, anatomically, physiological aging and degeneration of proprioception and the vestibular system occurs. In addition, muscle mass decreases and postural sway increases, so the reaction time of the motor nerve becomes slower until changes ultimately occur in balance control, which increases the frequency of falls[24]. Liu-Ambrose et al.[14] randomly divided 74 elderly people older than 70 years of age into an experimental group, which included 36 subjects, and a control group, which included 38 subjects. Otago exercise was performed in the experimental group for six months; for static balance, postural sway showed a decrease, from 360.3 mm to 305 mm, and dynamic balance, which was tested using the Timed Up and Go Test, decreased from 14.2 s to 13.6 s. In addition, Campbell et al.[25] divided 233 elderly women into an experimental group, which included 116 subjects, and a control group, which included 117 subjects. Otago exercise was performed for six months; the 4-test balance score showed a significant difference, from 0.42 to −0.01 (p<0.05). In this study, the BBS score for the augmented reality- based Otago exercise group showed a significant increase, from 47.60 to 53.70 (p=0.000); a significant increase, from 48.91 to 52.45 (p=0.001), was observed in the Otago exercise group, corresponding to findings of previous research. This means that Otago exercise might affect improvement in the ankle strategy and hip strategy. In the ankle strategy, the body can move as a single entity about the ankle when the foot muscle is activated on the ground[26]; Otago exercise was helpful in walking, standing erect, control of the body when it moves in a small range of area, and regaining balance when moving unconsciously. The hip strategy is used when the body moves faster as the velocity increases along with the distance[26]; Otago exercise helped walking posture with regard to movement correction and muscle activation pattern and the helped with balance control with regard to the base of support. Finally, we assume that augmented reality is a medium for helping the ankle and hip strategy by allowing individuals to visually compare the modeled motion and self motion.

An independent gait makes life productive, and is the most efficient method of moving from one place to another[27]. As the elderly age, aerobic capacity, joint flexibility, muscle strength, and bone mass decrease, so that gait velocity and cadence decrease, step length and stride length decrease, double leg support time increases, and heel off and arm swing decrease, resulting in an unstable gait pattern[28]. Binns[29] divided women older than 80 years into an experimental group, which included 19 subjects, and an control group, which included 18 subjects; Otago exercise was performed in the experimental group for six months; gait velocity increased from 0.80 m/s to 1.10 m/s. In this study, the augmented reality-based Otago exercise group showed a significant increase, from 0.79.8 m/s to 0.99.2 m/s (p=0.001), which corresponded with results of previous research. We assume that this is affected by backward walk, walking and turning around, heel to toe walking, and stair walking in the Otago exercise program. The subjects worked on speed, distance, direction, rhythm and muscle tone, and strength while walking. In addition, through stair walking, the subjects practiced with a fixed foot support, acceleration, balance control, extension and contraction of the lower limb, and ankle dorsiflexion to move the center of gravity to control the afferent, efferent, and contraction of the lower limb muscles. As a result, coordination and weight shifting were learned through movement of the lower limbs, and this improvement resulted in an increase in step length of the right lower limb and stride length of both lower limbs, thereby improving gait velocity and cadence.

Self-efficacy is the self-belief or capability to create a plan and implement it. This efficacy also affects elderly, and decreases as people grow older, and it can be a hazardous factor for falls[5]; in addition, fear, which is the most significant complication of falls, should be regarded as an important matter[30]. Campbell et al.[31] divided 233 women older than 80 years of age randomly into an experimental group, which included 116 subjects, and a control group, which included 117 subjects; Otago exercise was performed in the experimental group for six months; fall efficacy showed a significant difference, from 93.3 to 91.9 (p=0.009). Two years later, Campbell et al.[31] traced 41 subjects in the experimental group, and 61 subjects in the control group and found that the falls efficacy changed from 91.0 to 89.4, which was statistically significant (p=0.03). In this research, the falls efficacy in the augmented reality-based Otago exercise group showed a significant difference (p=0.019), from 14.50 to 11.80, which corresponded with the previous research. This was the result of repeated training with the augmented reality program and the head-mounted display, which isolated the subjects from the external environment in order to increase concentration. Thornton et al.[32] have shown that virtual reality participants had greater improvements in quantitative measures and made more comments expressing enjoyment and improved confidence. An augmented reality environment can provide users with direct visual feedback to control their movement and watch their own movement at the same time[33]. It implies that Otago exercise based on augmented reality can draw a user's interest and influence the falls efficacy. In addition, the improved gait of subjects in the augmented reality-based Otago exercise group resulted in increased mobility, which helped in performance of activities of daily living and social activities and was also related to positive physical activity. In this study, we assume that the augmented reality program represented repeated feedback, and the Otago training represented a goal of the subjects, which they could achieve by succeeding at each level, and that self-pride increased. The increase in self-pride was related to self-efficacy, which leads to an increase in falls efficacy. Therefore, repetitive training using the augmented reality-based Otago exercise for fall prevention leads to a decrease in the fear of falls in elderly women and even changes their behaviors.

This research showed that augmented reality-based Otago exercise is effective for improving balance, gait, and falls efficacy of elderly women and that application of augmented reality-based Otago exercise is meaningful. We expect that this augmented reality-based Otago exercise will be used in elderly care centers as a physical therapy for effective training for balance, gait, and falls efficacy, and it could be used as a database for rehabilitation. We also hope that augmented reality-based rehabilitation research will be conducted continuously.

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