J. Phys. Ther. Sci. 29: 1586–1589, 2017

The Journal of Physical Therapy Science

Original Article

Effects of augmented reality-based Otago exercise on balance, gait, and physical factors in elderly women to prevent falls: a randomized controlled trial

Jin Lee, PT, MSc[1)], Ha-na Yoo, PT, Msc[1)], Byoung-Hee Lee, PT, PhD[2)*]

[1)] *Graduate School of Physical Therapy, Sahmyook University, Republic of Korea*
[2)] *Department of Physical Therapy, Sahmyook University: 815 Hwarang-ro, Nowon-gu, Seoul 139-742, Republic of Korea*

Abstract. [Purpose] To determine the effect of augmented reality (AR)-based otago exercise on muscle strength, balance, and physical factors in falls of elderly women. [Subjects and Methods] Thirty subjects were randomly assigned to AR group (AR, n=10), yoga group (yoga, n=10), and self-exercise group (self, n=10). For 12 weeks, these groups were given lessons related to AR-based otago exercise including strengthening, balance training, or yoga three times a week (60 minutes each time) and self-exercise using elastic band exercise program. [Results] Knee flexion and ankle dorsiflexion strength were significantly improved in all three groups (AR, yoga, and self-exercise groups). Regarding balance, eye open center of pressure-x (EO CoP-x) was significantly decreased in AR group and yoga group. However, eye close CoP-x, eye open standard deviation-x (EO SD-x), and eye open height of ellipse (EO HoE) were only significantly decreased in AR group. AR group also showed meaningfully improved results in morse fall scale. [Conclusion] Augmented reality-based otago exercise can improve muscle strength, balance, and physical factors in elderly women to prevent falls.

Key words: Aged, Augmented reality, Fall

(This article was submitted Apr. 24, 2017, and was accepted Jun. 8, 2017)

INTRODUCTION

For the elderly, 27.7% of those in their 70s, 46.4% of those in their 80s, and 64.8% of those in their 90s who suffer from fall injury will die from it[1)]. Falls have negative effects on the quality of life of patients depending on their gender, physical activities, nutrition, dose of medicine, fear of fall, treatment of fall, social environment, and financial status[2)]. For the elderly, loss of muscle strength in the lower body is greater than that in the upper body. Decreased muscle strength in the knee can lead to body wavering above the bearing surface when standing[3)]. Therefore, the elderly must maintain and improve their muscle strength by performing exercise and physical activities to prevent falls[4)].

May exercises have been designed to prevent falls, including balance exercises on unstable and stable grounds[5)], muscle-strengthening exercises using elastic bands, endurance exercises using stationary bicycles[6)], yoga exercise in order to increase stationary body posture and flexibility, and Tai-chi[7)]. Otago Exercise Program consists of progressive-resistance strength exercises, balance exercises related to everyday activities, and aerobic exercises supplemented with walking periods[8)]. It can improve muscle strength, functional balance, and physical performance of older adults[9)]. Augmented reality (AR) is a technique that bolsters its veridical effectiveness in combination with a virtual concept by providing a sense of realism and additional information[10)]. Virtual reality (VR) based application is playing an increasing role in motor rehabilitation. It

*Corresponding author. Byoung-Hee Lee (E-mail: 3679@syu.ac.kr)

provides interactive and individualized environment. In addition, it increase motivation during motor tasks and facilitates motor learning through multimodal sensory information[11]. Therefore, the objective of this study was to determine the effect of AR Otago exercise on muscle strength, balance, and other physical factors in elderly women to prevent falls.

SUBJECTS AND METHODS

A total of 30 elderly women were selected from the N-region of Seoul, Korea. Inclusion criteria were: those who had no cardiovascular disease, those who received a score of 24 or higher in the Korean version of mini-mental state exam which could allow them to communicate and understand research material, those who had no impairment in visual sense or hearing sense including vestibule, those who had no missing limbs, and those who had not experienced any bone damage in the past year. Procedures and objective of this research were explained to these participants. They were randomly divided into AR Otago exercise group, yoga group, and Self-Otago exercise group. All three groups were trained for 12 weeks (3 sessions per week, 60 minutes per session). For 10 subjects in the AR group, their mean age, height, weight, and body mass index (BMI) were 72.60 ± 2.67 years, 150.49 ± 3.28 cm, 58.62 ± 5.22 kg, and 25.89 ± 2.34, respectively. For the 10 subjects in the yoga group, their mean age, height, weight, and BMI were 75.80 ± 5.47 years, 148.48 ± 4.81 cm, 54.95 ± 9.09 kg, and 24.91 ± 2.30, respectively. For the 10 subjects in the self- Otago exercise group, their mean age, height, weight, and BMI were 76.40 ± 5.54 years, 147.20 ± 4.10 cm, 55.30 ± 3.31 kg, and 25.52 ± 1.11, respectively. The present study was approved by Institutional Review Board of Sahmyook University (Approval No.: 2-1040781-AB-N-01- 2017015HR). Each participant was able to follow instructions. Informed consent was obtained from each participant.

All subjects were assessed using Manual Muscle Test (MMT), Force Plate (FP), and Morse Fall Scale (MFS). AR based Otago group were subjected to the following muscular improvement training program: knee flexion exercise, walking backwards, walking and turning around, walking in a straight line, standing on one leg, walking on heels, walking on toes, walking backwards on toes and on heels, standing up from sitting position, and walking up stairs[12]. For subjects in the yoga group, group yoga exercise program consisting of cat pose, tree pose, cobra pose, triangle pose, twist pose, leg stretch, and pigeon pose was used. For participants in the Self-Otago group, fall prevention education was provided to participants once. They were asked to read the provided printouts. They were suggested to follow the Otago exercise program once every Monday. A therapist called the participant and asked her whether she did the suggested exercise. Information about their health condition and whether they fell recently was also obtained.

A digital manual muscle tester (model 01163, Lafayette, USA, 2003) was used to measure muscle strength of knee flexion, ankle dorsiflexion, and ankle palntarflexion[13]. Balance ability was assessed using a Foot Print (model PDM-S, Zebris Medical GmbH, Germany, 2007). To analyze static and dynamic load distribution, the patient was placed on the platform of the Foot Print in the middle. The right foot should hit the right side of the platform while the left foot should hit the left side of the platform. The feet should be separated in the front and rear by the mid-line. Fall efficacy was measured using short Morse Fall Scale (MFS) to measure confidence regarding fall prevention. Sardo et al.[14] have selected seven items for the MFS out of 6 items of MFS. The original questionnaire contained 6 items scored in a four-point scale. Lower scores indicated higher confidence in fall prevention.

SPSS 19.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Kolmogorov-Smirnov test was used to test the distribution of general characteristics and outcome measures of subjects. Paired t-test was used to compare pre- and post- test measurements of muscle strength, balance, and prevention of falls within groups. Independent t-test was used to compare differences in muscle strength, balance, and prevention of falls before and after training between groups. Significance level was set at $p<0.05$ for all analyses.

RESULTS

Knee flexion and ankle dorsiflexion strength were significantly ($p<0.05$) improved in all three groups (AR, yoga, and self-Otago exercise groups). Regarding balance, eye open center of pressure-x (EO CoP-x) was significantly ($p<0.05$) decreased in AR group and yoga group. However, eye close center of pressure (EC COP-x), eye open standard deviation-x (EO SD-x), and eye open height of ellipse (EO HoE) were only significantly decreased in the AR group. AR group also showed meaningfully ($p<0.05$) improved results in morse fall scale. Knee flexion strength, EC CoP-x, EO SD, and EO HoE were significantly different among the three groups (Table 1).

DISCUSSION

Muscle strength is decreased 30% for people in their 70s compared to that in their 50s. It is decreased exponentially in people in their 80s[15]. For the elderly, loss of muscle strength in the lower body is greater than that in the upper body. This is one reason behind their decreased walking speed and higher frequency of falls[4]. However, inactivity and aging both have been found to important factors associated with decreased muscle strength in the elderly. Inactivity decreases muscle functionality, flexibility, and strength. It has been reported that inactivity can induce higher muscular atrophy rate compared to aging[16]. In this study, both knee flexion and ankle dorsiflexion strength were significantly ($p<0.05$) increased in all three

Table 1. Comparison of muscle strength, balance and fall efficacy as measured within and between groups (N=30)

Parameters	Values						Change values		
	AR based Otago group (n=10)		Yoga group (n=10)		Self-Otago group (n=10)		AR based Otago group (n=10)	Yoga group (n=10)	Self-Otago group (n=10)
	Pre	Post	Pre	Post	Pre	Post	Post-Pre	Post-Pre	Post-Pre
MMT (kg)									
Rt. dorsiflex	11.20 (2.57)[a]	18.92 (2.88)‡	7.13 (2.46)	16.43 (3.53)‡	13.36 (4.48)	18.92 (2.68)*	7.71 (3.97)	9.29 (4.15)	5.55 (5.62)
Lt. dorsiflex	9.52 (2.77)	18.28 (5.21)‡	7.79 (2.48)	14.87 (3.13)‡	13.35 (6.08)	19.24 (4.92)*	8.75 (4.88)	7.08 (3.86)	5.89 (7.14)
Rt. ham	12.44 (5.75)	27.66 (3.57)‡	9.53 (1.79)	22.38 (4.48)‡	18.57 (5.78)	25.04 (2.57)*	15.21 (4.40)†	12.84 (4.65)	6.47 (7.16)
Lt. ham	13.39 (5.90)	28.01 (3.62)‡	9.73 (1.62)	23.06 (3.85)‡	18.76 (5.98)	25.04 (2.57)*	14.62 (4.57)†	13.32 (3.80)	6.70 (6.81)
Balance (cm)									
EO CoP-x	16.90 (2.23)	15.90 (2.07)*	18.05 (1.38)	16.66 (1.30)*	17.80 (0.93)	17.06 (1.42)	–1.00 (1.07)	–1.38 (1.50)	–0.74 (1.45)
EC CoP-x	16.50 (1.58)	15.52 (1.66)*	17.33 (1.18)	16.63 (1.20)	17.32 (1.25)	16.59 (–1.35)	–0.98 (0.98)	–0.70 (1.25)	–0.73 (1.36)
EO SD-x	0.50 (0.19)	0.36 (0.97)*	0.37 (0.10)	0.38 (0.10)	0.41 (0.08)	0.42 (0.12)	–0.13 (0.12)†	0.01 (0.07)	0.01 (0.05)
EO HoE	3.61 (1.31)	2.78 (0.52)*	3.83 (0.71)	3.75 (1.16)	3.61 (1.31)	3.61 (1.31)	–0.82 (0.90)†	0.12 (0.54)	0.09 (0.48)
Fall down									
MFS (score)	23.00 (19.60)	13.00 (11.83)*	15.50 (14.61)	12.50 (11.84)	10.00 (9.12)	12.50 (13.17)	–10.00 (12.24)	–3.00 (9.77)	2.500 (8.89)

[a]Values are Mean (SD), AR: augmented reality; MMT: Manual Muscle Test; EO: eye open; EC: eye close; CoP: center of pressure; HoE: height of ellipse; MFS: Morse Fall Scale, *p<0.05, †p<0.01, ‡p<0.001

groups (AR, yoga, and self-Otago exercise groups). Liu-Ambrose et al.[17] have also found that hip flexion muscle strength in significantly (p<0.05) increased in the Otago group in their study after 74 older adults were divided into Otago group (n=36) and control group (n=38). The Otago group attended Otago exercise three times a week for 6 months (40 min each time).

Knee flexion, tibialis anterior, ankle planter, and dorsiflexion are all involved in Otago exercise. The exercise might have invigorated these muscles, increasing the synthesis of actin and myosin (myofibrillar proteins), thus increasing muscle cross-sectional area and muscle strength during the process. In addition, muscle strength training of Otago exercise is a repeated resistance exercise. It might have prevented inactivity in the elderly. With this exercise, the performance capability of muscle fibers was maximized, allowing the elderly to successfully raise legs when instant alteration in gait-pattern took place in order to dodge obstacles during gait. Therefore, it might have helped the elderly acquire muscle strength needed to prevent falls.

Balance is a process that we use to control the center of mass in accordance to the base of support whether we are in motion or at stationary phase[18]. In this study, EO Cop-x, EC Cop-x, SD-x, and HoE were significantly (p<0.05) decreased in the AR group. In the study of Liu-Ambrose et al.[17], seventy-four participants with older adults were divided into two groups (Otago group, n=36; control group, n=38). The Otago group attended Otago exercise three times a week for 6 months (40 min each time). They found that postural sway and time in the up and go test were significantly decreased (p<0.05) in the Otago group. In a research study conducted by Benavent-Caballer et al.[12], fifty-two older adults were divided into 2 groups (Otago group, n=23; control group, n=28). The Otago group attended 46 sessions of Otago exercise for 4 months (60 min each session). Scores of One Leg Standing test (OLS), TUG, and Short Physical Performance Battery (SPPB) were significantly decreased while scores of Berg Balance Scale (BBS) and 6-minuite Walk Test (6MWT) were significantly increased (p<0.05) in the Otago group. Otago exercise might have relaxed joint capsules, increased joint movement angle, and applied stress to joint capsules, thus preventing adhesion to collagen tissue. Hence, augmented joint activity might have promoted activity of synovial fluid and accelerated nutrition supply to the joint, resulting in activation of joint receptors. Balance training provided by the AR Otago exercise might have also improved both ankle and knee.

Fall is a worldwide health problem among elderly people. Approximately 30% of community dwellers aged 65 and older fall annually. Falls are not only associated with morbidity, but also associated with mortality in the older population[19]. In this study, MFS was only significantly (p<0.05) decreased in the AR group. In a research conducted by Dadgari et al.[20], 317 older adults were divided into two groups (Otago group, n=160; control group, n=157). The Otago group attended Otago exercise three times a week for 6 months (45–60 min each time). FES score was found to be significantly decreased in the Otago group (p<0.05).

In summary, Otago exercise is a fall prevention exercise program for the elderly. Its participants have experienced increase in activity (both physical activity and social activity). Such increase in activity might have stimulated participant's confidence, therefore decreasing the risk of falls.

Conflict of interest

Financial disclosure statements have been obtained, and no conflicts of interest have been reported by the authors or by any individuals in control of the content of this article.

REFERENCES

1) Cao ZB, Maeda A, Shima N, et al.: The effect of a 12-week combined exercise intervention program on physical performance and gait kinematics in community-dwelling elderly women. J Physiol Anthropol, 2007, 26: 325–332. [Medline] [CrossRef]
2) Prata MG, Scheicher ME: Effects of strength and balance training on the mobility, fear of falling and grip strength of elderly female fallers. J Bodyw Mov Ther, 2015, 19: 646–650. [Medline] [CrossRef]
3) Spirduso WW, Francis KL, MacRae PG: Physical dimensions of aging. Champaign: Human Kinetics, 2005.
4) Bonder B, Dal Bello-Haas V: Functional performance in older adults. Philadelphia: F.A. Davis Company, 2009.
5) Bishop MD, Meuleman J, Robinson M, et al.: Influence of pain and depression on fear of falling, mobility, and balance in older male veterans. J Rehabil Res Dev, 2007, 44: 675–683. [Medline] [CrossRef]
6) Buchner DM, Cress ME, de Lateur BJ, et al.: The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. J Gerontol A Biol Sci Med Sci, 1997, 52: M218–M224. [Medline] [CrossRef]
7) Raub JA: Psychophysiologic effects of Hatha Yoga on musculoskeletal and cardiopulmonary function: a literature review. J Altern Complement Med, 2002, 8: 797–812. [Medline] [CrossRef]
8) Gardner MM, Buchner DM, Robertson MC, et al.: Practical implementation of an exercise-based falls prevention programme. Age Ageing, 2001, 30: 77–83. [Medline] [CrossRef]
9) Robertson MC, Campbell AJ, Gardner MM, et al.: Preventing injuries in older people by preventing falls: a meta-analysis of individual-level data. J Am Geriatr Soc, 2002, 50: 905–911. [Medline] [CrossRef]
10) Espay AJ, Baram Y, Dwivedi AK, et al.: At-home training with closed-loop augmented-reality cueing device for improving gait in patients with Parkinson disease. J Rehabil Res Dev, 2010, 47: 573–581. [Medline] [CrossRef]
11) Ferreira Dos Santos L, Christ O, Mate K, et al.: Movement visualisation in virtual reality rehabilitation of the lower limb: a systematic review. Biomed Eng Online, 2016, 15: 144. [Medline] [CrossRef]
12) Benavent-Caballer V, Rosado-Calatayud P, Segura-Ortí E, et al.: The effectiveness of a video-supported group-based Otago exercise programme on physical performance in community-dwelling older adults: a preliminary study. Physiotherapy, 2016, 102: 280–286. [Medline] [CrossRef]
13) Durmus B, Baysal O, Altinayar S, et al.: Lower extremity isokinetic muscle strength in patients with Parkinson's disease. J Clin Neurosci, 2010, 17: 893–896. [Medline] [CrossRef]
14) Sardo PM, Simões CS, Alvarelhão JJ, et al.: Fall risk assessment: retrospective analysis of Morse Fall Scale scores in Portuguese hospitalized adult patients. Appl Nurs Res, 2016, 31: 34–40. [Medline] [CrossRef]
15) Lindle RS, Metter EJ, Lynch NA, et al.: Age and gender comparisons of muscle strength in 654 women and men aged 20–93 yr. J Appl Physiol 1985, 1997, 83: 1581–1587. [Medline]
16) Bottomley JM, Lewis CB, Lewis CB: Geriatric rehabilitation: a clinical approach. Upper Saddle River: Pearson/Prentice Hall, 2008.
17) Liu-Ambrose T, Donaldson MG, Ahamed Y, et al.: Otago home-based strength and balance retraining improves executive functioning in older fallers: a randomized controlled trial. J Am Geriatr Soc, 2008, 56: 1821–1830. [Medline] [CrossRef]
18) Janusz BW, Beck M, Szczepańska J, et al.: Directional measures of postural sway as predictors of balance instability and accidental falls. J Hum Kinet, 2016, 52: 75–83. [Medline] [CrossRef]
19) Ambrose AF, Paul G, Hausdorff JM: Risk factors for falls among older adults: a review of the literature. Maturitas, 2013, 75: 51–61. [Medline] [CrossRef]
20) Dadgari A, Aizan Hamid T, Hakim MN, et al.: Randomized control trials on otago exercise program (oep) to reduce falls among elderly community dwellers in shahroud, iran. Iran Red Crescent Med J, 2016, 18: e26340. [Medline]