# THE EFFECT OF REPEATED BALL TARGETING EXERCISE ON COGNITIVE FUNCTION, PROPRIOCEPTION AND MOTOR CONTROL ACCORDING TO DIFFERENT AGE GROUPS



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## ABSTRACT

The purpose of this study was to analyze the effects of repeated ball targeting exercise on cognition function and motor control in healthy women according to different age ranges. A total of 30 healthy women were assigned to 5 different groups according to their age range. The cognitive test, joint position sense (JPS), and the handgrip strength test were performed before and after the training. One-way ANOVA was used to compare the between-group differences and the Paired-t-test was used to evaluate the pre-post changes within groups. As the result, cognition function scores and JPS error rates showed significant differences before and after the intervention ($p<0.05$). However, there was no significant difference in handgrip strength before and after the experiment ($p>0.05$). We observed a clear difference in the mean cognitive score and JPS between the different age ranges. Statistically significant differences were observed between the 20s and 60s, 30s, and 60sin the cognitive function scores, and the error rates of JPS angles showed a decreased angle in the 60s compared to the 20s. We can affirm that there is a positive correlation between physical exercise, cognitive function, and proprioception in elderly people.

**Keywords:** cognitive ability, motor control, proprioception, targeting exercise

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## INTRODUCTION

Modern society is rapidly aging. Aging is responsible for cognitive function decrease and damage to the hippocampus [1]. Aging is a powerful risk factor for dementia. Especially important in Korea, where occur of dementia is increasing dramatically [2]. Dementia is considered an important issue in all countries including in East Asia [3]. Although treatment for dementia and cognitive impairment is under constant study, most of these interventions involve invasive preparations related to increased risk of side effects and complications [4].

Cognitive ability refers to vocabulary, attention (concentration), delayed recall, intelligence, problem-solving, and behavior inhibition. It is mainly related to frontal lobe function, and it means performing executive functions [5]. The difference in cognitive ability between men and women appears after menopause in women aged 40 to 60. With menopause symptoms, many women experience cognitive function decline because of less estrogen secretion [6]. Therefore, women's cognitive ability will decrease further as they age. Previous studies have shown that physical exercise can prevent or delay aging-related diseases, including dementia [7]. Proper physical activity requires proprioceptive sensory training [8]. The proprioceptive sense is defined as the ability to recognize the joint position and movement and force of the body [9]. Brain structural changes with age are associated with proprioception deterioration [5]. Various studies have demonstrated that proper proprioceptive training improves proprioception. Through this, it can be seen that proprioceptive training helps motor control by improving somatosensory [8].

Previous studies suggested that postural stability and balance adjusting ability related to proprioceptive

tion after ball throwing exercise may be improved [10]. The ball targeting exercise that we would like to implement in the present study is not a muscle-centered exercise, but a repeated ball throwing exercise toward the goal. This stimulates the autonomic nerves of the hand and improves the cognitive function of the participants in muscle movements, including hand movements and visual movements [11]. In addition, a study has shown that repetitive passive movement has improved joint position sense by providing benefits to propulsion. Research has shown that repeated passive movement provides advantages to propulsion and improves joint position sense [12,13]. This can be expected to affect recognition and motor control in this study.

Previous studies have shown many positive aspects of the musculoskeletal system due to repeated physical activity. In addition, studies have shown a positive connection between physical exercise and cognition, especially in older people aged 65 and over [14]. In one study, it was said that various mechanisms such as physical activity and exercise had positive effects on cognitive function. In one study, it was said that various mechanisms such as physical activity and exercise had positive effects on cognitive function [7]. However, there are few studies on the correlation between hand motor function and dementia and cognitive function, and few studies on the correlation between cognitive and motor control from repeated targeting exercise. Therefore, the purpose of this study was to divide the age groups based on healthy women to find the positive effects of recognition and motor control after repeated ball targeting exercise. In addition, we would like to confirm that the elderly is higher than the younger ones by comparing the effects by age.

**2.**

**2.1.**

This study was a cross-sectional study and non-equivalent multiple group comparison design. The participants of the study consisted of 30 healthy women in their 20s to 60s who were recruited through interviews and received full explanations regarding the study purpose and procedure. We included only those who agreed to participate voluntarily in the study and the criteria for selection were as follows: 1) no musculoskeletal diseases within the last 6 months, 2) no history of neurological disease and mental illness within the last 6 months, 3) not involved in taking drugs related to mental illness such as depression, 4) able to read and understand instructions, and 5) healthy woman who understand the purpose of this study and able to perform physical exercises. The mean age of the subjects was 43.47 years old, and the mean height and weight were 160.2cm and 56.19kg respectively. The general characteristics of the participants are presented in [Table 1]. This study received the approval of the Institutional Review Board of Sunmoon University (SM-202104-042-2). Participants were divided into 5 groups of 6 individuals each (20s, 30s, 40s, 50s, 60s).

**Table 1.** General characteristics of the participants

| Characteristic | Values |
|---|---|
| Gender(female) | 30 |
| Age(year) | 43.47±15.07 |
| Height(cm) | 160.2±5.37 |
| Weight(kg) | 56.19±8.32 |

mean±standard deviation

**2.2. Intervention methods**

The subject stood shoulder-width apart and holds a ball with one hand at the shoulder level. Then, they were instructed to throw the ball toward the target point attached to the wall. Repeated the ball targeting exercise 30 times/set for 3 sets with 2 minutes of rest per set. The exercise sessions were conducted indoors with full lighting, and additional breaks were allowed as needed. Two practices were given before the experiment to familiarize with the procedure. The total time of the session was about 15 minutes. In all experiments, non-slip pads were attached to prevent the risk of falls, and the investigator assisted the participants from the side. The distance from the target point was 3m, and the weight of the ball was 100g with 20cm in diameter.

**2.3. Measurement methods and tools**

We conducted three outcome measurements before and after the intervention (cognitive function test, joint position sense test, and handgrip strength) to evaluate cognition, proprioception, and motor control.

#### 2.2.2. Cognitive function measurement

In this study, we used the Cognitive Screening Assessment System (CoSAS) to evaluate cognitive ability. The CoSAS software was installed on a tablet PC. This computerized version of the cognitive ability test evaluates a total of six cognitive abilities which are visual perception, memory, attention, language, orientation, and metacognition. The test results were evaluated as 0-100 points and classified into 0-31.12 = cognitive risk group, 31.13-62.23 = cognitive boundary group, and 62.24-100 = cognitive normal group, with a higher score meaning less severe cognitive disability. Cognitive function was measured twice, before and after the intervention.

#### 2.2.3. Joint position sense measurement

In this study, the joint position sense measurement was used as a measurement of the motor control function. This test was used as an indicator to confirm the change in the proprioception sensor. We used the Goniometer for the measurement and the examiner manually the joint position. The elbow was flexed at 75° and placed in a neutral position perpendicular to the table. The wrist was in a neutral position and the finger slightly flexed. In that position, the examiner participants were instructed to bend the other arm at the same angle as the manually placed arm in a situation. Participants' vision was blocked by putting on a blindfold. The examiner measured the angle of active elbow bending with a goniometer. To calculate the absolute score, repeated the tests five times and record the mean error value as the joint position sense's score. The mean error value was represented by the joint position sense error rate.

#### 2.2.4. Handgrip strength measurement

For the handgrip strength measurement, we used the Micro 4 Pinch and grip. The unit of measurement of the grip force was Ib. Before the intervention, in order to set the criteria for handgrip strength of the participants, they were instructed to hold the grip force with their maximum force for 3 seconds. One time practice was given before the measurement. The measurement was performed by requesting to be held at the same intensity as for the first practice. To calculate the absolute score, the test was repeated five times and the mean error value was recorded as the handgrip strength score. The mean error value was represented by the grip error rate.

### 2.4. Data Analysis

All data measured in this study were analyzed using the IBM SPSS Statistical software (version 28.0). Descriptive analysis was used to analyze participants' demographic information and all the data are presented as mean±standard deviation. One-way ANOVA was used to determine the difference in cognition, JPS, and handgrip strength between the groups, and Bonferroni analysis was used for the post-hoc test. A paired t-test was used to determine the difference between the pre-post variables of the exercise program within the groups. The statistical significance level of this study was set to $\alpha = 0.05$.



## 3. Results

In this study, the mean scores, and standard errors of cognition, JPS, and grips according to age ranges are presented in [Table 2]. In Cognition function, there was no significant difference in the pre-experiment mean score according to age of 20s to 60s groups ($p>0.05$). However, there was a significant difference in post-experiment mean scores according to the different age ranges ($p<0.05$). The difference in mean score in post-experiment showed significantly different between the 20s and 60s, 30s and 60s ($p<0.05$). In JPS, there was no significant difference in the pre-experiment mean score according to the age of 20s to 60s groups ($p>0.05$). However, there was a significant difference in post-experiment mean scores according to the age ranges ($p<0.05$). The difference in mean score in post-experiment showed significantly different between the 20s and 60s ($p<0.05$). Regarding the handgrip strength, there was no significant difference in the pre-experiment mean score according to the age ranges ($p>0.05$). Additionally, we did not observe a significant difference in post-experiment mean scores according to the age of 20s, 30s, 40, 50s, and 60s groups ($p>0.05$).

The comparison before and after the experiment was represented in [Table 3]. As a result, cognition function scores and JPS error rates showed significant differences ($p<0.05$). However, there was no significant difference in handgrip strength before and after the experiment ($p>0.05$).

**Table 2.** Comparison of pre-post differences in cognition, JPS, and grip between ages (One-way ANOVA)

| | | A=20s | B=30s | C=40s | D=50s | E=60s | *F*(p) |
|---|---|---|---|---|---|---|---|
| Cognition (score) | pre | 93.85±7.20 | 88.86±4.74 | 87.89±6.34 | 89.02±7.91 | 82.42±6.21 | 2.308(0.086)* |
| | post | 98.48±2.51 | 99.50±1.22 | 94.76±4.41 | 96.75±3.13 | 91.71±4.17 | 5.317(0.003)** |
| JPS (angle) | pre | 3.53±1.51 | 4.23±2.55 | 4.63±1.77 | 5.90±2.80 | 7.73±3.93 | 2.328(0.084)* |
| | post | 1.73±.82 | 2.40±1.12 | 2.93±1.10 | 3.60±2.81 | 5.03±2.48 | 2.774(0.049)** |
| Grip (lb) | pre | 3.16±2.40 | 3.30±1.47 | 2.13±1.43 | 3.47±1.26 | 2.83±0.82 | 0.681(0.612) |
| | post | 3.57±.70 | 2.17±.83 | 1.87±.37 | 2.60±1.54 | 2.50±1.01 | 2.623(0.059)* |

*p < 0.1, **p < 0.05, ***p < 0.01, mean ± standard deviation, Cognition: CoSAS score, JPS: joint position sense, Grip: hand grip strength

**Table 3.** Comparison of pre-post differences in cognition, JPS, and grip within groups (Paired t-test)

| | Pre-test | Post-test | T | P |
|---|---|---|---|---|
| Cognition (score) | 88.40±7.13 | 96.63±3.59 | -9.039 | 0.001*** |
| JPS (angle) | 5.20±2.89 | 3.14±2.07 | 7.002 | 0.001*** |
| Grip (lb) | 2.98±1.53 | 2.54±1.08 | 1.577 | 0.126 |

*$p$ < 0.1, **$p$ < 0.05, ***$p$ < 0.01, mean ± standard deviation, Cognition: CoSAS score, JPS: joint position sense, Grip: hand grip strength

## 4. DISCUSSION

The purpose of this study was to investigate the positive effects of repeated ball targeting exercises on cognition, proprioception, and motor control in 30 healthy women between the ages of 20 and 60 years old. Generally, cognition and exercise control decreased with age [1,15]. Entering an aging society, the proportion of the population aged 65 or older has expanded, and health and cognitive management of the population was a continuous concern, and research on this topic is being actively conducted [16]. In the previous studies, it has been verified through several studies that physical activity participation has the effect of improving cognitive function or delaying aging-related cognitive degradation as well as demonstrating that ball-based physical exercise has a positive effect on cognition [17,18]. Therefore, this study set physical activity as ball targeting excise that requires concentration and motor control and investigated its effect on cognition and exercise control. In this study, when repeated ball targeting exercises were performed by age group, the scores of cognitions, JPS, and handgrip strength were measured before and after the exercise. As a result of the experiment, when comparing scores by age group, it was shown that cognition and JPS showed a significant difference and had a positive effect on ball-targeting exercise. The study result suggests that repetitive passive movement influenced proprioception and improved JPS was consistent that repeated ball targeting exercises in this study improved JPS, often clinically referred to as propulsion [12,13]. Based on previous studies and the statistical results of this study, it was found that repeated ball targeting exercises were effective not only in improving joint position sense of motor control but also cognitive function.

However, regarding handgrip strength, statistically significant differences due to ball throwing movements were not observed. The handgrip strength test was used as a variable, fast, and reliable tool to test the vitality and physical function of the elderly population [19]. In this study, the effect of motor control was not shown in the handgrip strength test despite conducting the experiment after sufficient practice in advance. Considering that there should be a significant difference in the second re-

sult from the first due to the learning effect. The regulation of grip strength is a complex task which requires coordination of multiple muscles, and although it was difficult to obtain grip regulation ability only with our exercise training. It helped induce muscle strength, balance, and endurance improvement [20]. No statistically significant values were found in the results of this study. However, it was found that fine passive control was better in higher age groups after exercise [21]. In the experiment, handgrip control availability was induced, but handgrip strength increased. The reason for this was the correlation between handgrip strength exercises (pull-up, push-up, target shooting accuracy test) and target shooting accuracy [22]. In previous studies, only the elderly over 45 years of age were included. However, in the present study, participants' age varied from their 20s to 60s. In addition, in previous studies, subjects participated regardless of gender, but in this study, women were selected as subjects because they showed weaknesses in attention and memory due to hormonal changes and menopause [23]. Previous studies had found that physical activity programs centered on the elderly were effective in improving cognitive function as well as the physical function of the elderly [10]. A study that showed the link between physical exercise and cognitive improvement proved that it has a greater effect on cognitive improvement in the elderly aged 65 or older [14]. This was consistent with the fact that the elderly group had a relatively higher score improvement than the younger group when comparing the CoSAS mean score by age group in this study. This study was conducted to find out if there was any change in perception only by repeated targeting ball throwing without any additional intervention.

Efficient throwing exercises should optimally be displayed the timing of the trunk rotation, arm movement, targeting motion, and the muscles acting [24]. Throwing ability was not only affected by muscle strength and agility but also required attention to throwing at a particular target. According to James (1890), attention was defined as the concentration or focus of consciousness that selects one object or thought and keeps it clearly in the mind [25]. Concentration can be conceptualized as the ability to maintain attention to the selected stimulus for a limited time [26]. Archery and shooting in target sports such as ball targeting exercises all required a high level of concentration as well as muscle strength, proprioceptive sense, and balance [27]. When concentration decreases, not only does the accuracy decrease, but it is also difficult to throw to the target point. Self-regulation referred to the process of leading change using techniques or strategies to change one's behavior, which is the ability required for targeted sports [27]. Studies have confirmed that one of the most effective subjects of exercise is attention focused. The effect of this experiment on cognitive improvement can be confirmed by performing the concentration task of repeated ball throwing toward the target [28]. For example, it can be seen that dart-throwing exercises improve motivation, attention, performance, and learning by focusing on the target [29]. Through this, we can assume that throwing target sport influences improving attention. Active exercise increases blood flow in the brain and activates skeletal muscle contraction and autonomic nervous system changes. It can be seen that exercise-trained elderly people have higher cerebral blood flow and better cerebrovascular function, which can potentially inhibit brain cognitive function reduction. The central instruction of the brain begins skeletal muscle contraction and autonomic nervous system changes at the beginning of the exercise. Therefore, the direct effect of physical activity is largely embodied by cognitive function improvement and neuromorphological changes [15]. This can be seen as evidence that physical activity is one of the most influential factors in cognitive regulation. In particular, the more complex cognitive tasks, the more obvious the effectiveness of physical activity [28]. Previous studies showed that postural stability and balance adjustment were improved after ball throwing, also cognitive, muscle activation, and postural adjustment ability were improved [10].

Physical activities such as exercise not only improve muscle and cardiopulmonary function development but also improve sociality development education, relationship development, human recovery, and patience [30]. According to the theory, brain volume and gray matter volume decrease with age [15]. In a previous study on 59 elderly people, aerobic exercise increased the volume of gray and white matter on the surface of the brain, and the volume of blood vessels and cognitive improvement were related to aerobic exercise [31,32]. Through three months of aerobic exercise, it is suggested that regular aerobic exercise can prevent

cognitive deterioration, brain atrophy, and disease caused by aging. The results of three months of aerobic exercise showed that the increase in vascular volume and cognitive improvement of hippocampi dentate gyrus showed a correlation with aerobic exercise [33]. In other words, it could take the advantage of improving cognition, motor control, and socialization. Dementia reduces basic physical activity and reduces immune function. This complication can lead to death. It can be concluded that it is a good exercise to prevent degenerative diseases such as dementia in an aging age when the elderly population is increasing due to regular ball targeting exercises. Dementia reduces basic physical activity, weakens the body, and reduces immune function. Complications are more likely to occur due to this, leading to death. Studies have shown that there is a higher risk of dying after dementia, especially in people with dementia, especially cerebrovascular and respiratory diseases. Studies have estimated that there is a higher risk of death after the onset of dementia. In addition, the number of deaths from cerebrovascular and respiratory diseases increased compared to those without dementia [34]. Physical exercise can prevent or delay degenerative diseases and look forward to life expectancy [7].

Humans and animals show differences. Human upright walking and hand use due to morphological changes in wrist bones provide evolutionary advantages. Unlike animals, humans can perform daily life functions such as attention and task memory while walking upright [35]. Animals of primates can use joints such as shoulders and elbows. However, primates had lower accuracy than humans in terms of throwing targets. Accurate targeting is a unique field for only humans. These techniques include stone-throwing, golf, and dart throwing, which require wrist flexion. This is called a "precision grip." Humans have the ability not only to grasp accurately but also to use effective tools with their hands. In this respect, they differed from primates [36

The present study presents several limitations. First, it is difficult to generalize the results for all ages because each group consists of only six healthy women in their 20s and 60s. Second, since the experiment was conducted only on women, it is necessary to conduct additional experiments with men. Another limitation is the condition of the participants. All the participants were healthy people. Thus, our findings cannot be applicable to people with cognitive and motor control disorders or other similar heath conditions. Additionally, it is necessary to conduct long-term experimental research.

## 5. CONCLUSION



The purpose of this study was to investigate the positive effects of repeated ball targeting exercises on cognitive and motor control among 30 healthy women in their 20s and 60s. As a result, it was confirmed that repeated ball targeting exercise was effective in improving cognitive function and JPS and had no effect on grip. Therefore, it can be concluded that repeated ball throwing exercises are effective to slow down cognitive function due to aging. In this study, only women and single experiments were applied. It is judged necessary to reverify its effectiveness through long-term research including men.

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## AUTHORS CONTIBUTIONS

Conceptualization, Eun-Bi Jo and Ji-Young Hwang.; methodology, JaeHo Yu, DongYeop Lee, and JiHeon Hong; software, SeongGil Kim; formal analysis, JinSeop Kim.; investigation, Eun-Bi Jo and Ji-Young Hwang; data curation, Eun-Bi Jo; writing—original draft preparation, Eun-Bi Jo and Ji-Young Hwang; writing—review and editing, DongYeop Lee and JiHeon Hong; supervision, JaeHo Yu; funding acquisition, JaeHo Yu. All authors have read and agreed to the published version of the manuscript.

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