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The effects of strength exercise on hippocampus volume and functional fitness of older women

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ABSTRACT

Background: Various positive effects of exercise on older women have been identified in many studies. Despite the importance of preserving the health of brain as well as body, few studies have investigated the effects of strength exercise on the brain health of older women to date. This study aimed to identify the effects of 24 weeks of the Growing Stronger program on hippocampus volume and functional fitness of older women.
Methods: Twenty one older women aged 67 to 81 participated in this study. Growing Stronger, which is a strength exercise program that is safe and effective for women and men of all ages, was conducted. The 11 strength exercise group ($n = 11$) participated for 50–80 min a day three times per week for a total of 24 weeks. The control group maintained their lifestyles without any special intervention. Participants were given a pre-test (before applying for the program) and post-test (after 24 weeks) to identify effects of the program. The data were analyzed with repeated measures ANOVA.
Results: Hippocampus volume was significantly increased in the strength exercise group, but decreased in the control group. Moreover, there was an interaction effect ($p < 0.001$) between time and group. Strength exercise has improved upper and lower body strength, lower body flexibility, agility, and dynamic balance. Upper body flexibility significantly decreased in the strength exercise group, but there was no interaction between the strength exercise group and the control group.
Conclusion: The results of this study suggest that strength exercise has beneficial effects on hippocampus volume and functional fitness. Therefore, strength exercise can be an effective exercise for older women.

1. Introduction

During aging, our body undergoes gradual physiological and psychological changes (Fleg et al., 2005). Changes with aging include reduced muscular strength, muscular endurance, cardiorespiratory fitness, balance, and flexibility (Adrian, 1981). Declines in strength or muscle mass are influenced by factors such as a disease, genetics, and nutrition, but the most important factor leading to declines in strength of older people is lack of physical activity (Rikli and Jones, 2001). Although effects in individuals differ, the older generally undergo biological changes such as worsening health conditions that increase with age. However, increasing physical activity can recover declined strength and muscle mass, leading to functional improvement regardless of age (McCartney et al., 1996). Furthermore, studies and concerns regarding the importance and effects of physical activity are growing. In fact, physical activity has been shown to help improve health through many studies (ACSM, 2013; Hunter et al., 2004; Jessup et al., 2003; Taylor and Johnson, 2008).

These changes also influence the brain. Indeed, the number of brain cells begins at about 100 billion and then decreases by 5 billion per decade. Since brain cells decrease, brain function declines with age (Colcombe et al., 2003). The hippocampus is the structure in the brain responsible for consolidating memories, and becomes smaller with increasing age (Zhang et al., 2010). Furthermore as the hippocampus shrinks in late adulthood and it may lead to impaired memory and an increased risk for dementia (Erickson et al., 2011). Moreover, the hippocampus is affected early in Alzheimer's disease (Rodríguez and Verkhratsky, 2011).

The human brain has considerable neural plasticity, with the ability to form memories, adapt to various circumstances, and induce or recover from mental diseases. Recently, the role of neurogenesis in generation of the mature brain has emerged (Gu et al., 2012). Neurogenesis continues in hippocampus of mature mammals, and the hippocampus plays a key role in neural circuits that control emotion-memories. The hippocampus, which is the neural structure of the temporal lobe, is formed by

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overlapping layers of two thin neurons, the dentate gyrus (DG) and the Ammon's horn or Cornu Ammonis (CA). The main input entering the hippocampus is the entorhinal cortex. The entorhinal cortex sends information to the hippocampus through axon fibers known as the perforant path, which leads into dentate gyrus. Neurogenesis is the process of neuron formation. Neurons are fundamental cells that form nerves. According to the plastic model, while neurons die, the remaining ones continue to develop, allowing older adults to compensate for neuronal losses (Goh and Park, 2009). Several studies conducted in the past few years have shown that new neurons are formed constantly in the hippocampus and the olfactory bulb of all mammals (Cameron and Mckay, 2001).

The brain holds the key to living a long healthy happy life (Braverman, 2005). There are individual differences to the degree and rate of decline in hippocampus (Nyberg et al., 2012). Physical exercise is one important way to maintain brain function (Gomez-Pinilla, 2006) and, consequently, cognitive functioning (Dishman et al., 2006; Whitbourne and Whitbourne, 2010). One study showed that higher levels of aerobic fitness are associated with increased hippocampus volume in older humans (Erickson et al., 2009), while another suggests that cardiovascular fitness is associated with the sparing of brain tissue in aging humans and that aerobic fitness can maintain and enhance central nervous system health and cognitive functioning in older adults (Colcombe et al., 2006).

Aerobic exercise in particular appears to be most beneficial in preserving and maximizing the functioning of the brain (Colcombe et al., 2006). And several studies have investigated the relationship between hippocampus volume and the physical exercise, but most of these have involved animals and aerobic exercise (Colcombe et al., 2006; Erickson et al., 2010). Only few studies have investigated resistant exercise in older women. Resistance training, also known as resistance exercise or strength training is an exercise that involves the voluntary activation of specific skeletal-muscle groups against external resistance (Winett and Carpinelli, 2001).

Meanwhile, Xu et al. (2014) confirmed that women who strength trained exhibited better perfusion than women who did not. Strength training slows down the decline of resting cerebral perfusion that occurs with normal aging. Declines in cerebral perfusion or hypoperfusion are linked to detriments in physical health and declines in cognitive function including Alzheimer's and dementia. Bolandzadeh et al. (2015) has shown the beneficial effect of resistance training on cognitive function. During strength training, the motor nerve is repeatedly stimulated by a response signal from the sensory nerve to the brain's central nerve (Kenney et al., 2015). Strength training may be useful for as may be difficult for older women to perform aerobic or other exercises due to osteoarthritis and other diseases.

Therefore, an exercise program known as 'Growing Stronger,' which was developed at Tufts University (Medford, MA, USA), was investigated in this study. One of the best ways to keep muscles healthy and strong is through strength training. Indeed, studies at Tufts University have shown that strength training is one of the best ways to fight the weakness and frailty that can come with age. When conducted regularly, strength training builds bone and muscle and helps preserve strength, independence, and energy. The Growing Stronger program is shown to be safe and effective for women and men of all ages (Sequin et al., 2002). In the program, a gradual resistance is applied to muscles over the first four weeks with weight bearing in order to strengthen hypertrophy muscle and connective tissue during the period of adaptation. After improving muscle power, adjustable ankle weights and dumbbells are used. This method reduced the risks of injury associated with initial training and makes the execution of strength exercise safer. Based on these findings, it is important to evaluate the effects of strength training on hippocampus volume as a strategy to control neurogenesis. Therefore, the objective of this study was to identify the effects of 24 weeks of strength training on changes in hippocampus volume and functional fitness, and of older women.

2. Materials and methods

2.1. Participants

The sample consisted only of women due to potential sex differences in cognitive response to exercise (Colcombe and Kramer, 2003) and differences in muscular effects between men and women to strength training (Tracy et al., 1999). Twenty five older women aged 67 to 81 years from the Senior Citizen Centre in Yeonje-gu, Busan, South Korea understood and volunteered for this experiment. We randomly assigned 25 older women older than 65 who had not undergone regular exercise within 3 months into an exercise group with 13 individuals and a control group with 12 individuals each.

Among the 25 people in this experiment, four, 1 due to moving out of the area and 3 due to personal reasons, dropped out resulting in 11 individuals for the exercise group and 10 for the control group. Members of the strength exercise group participated in an exercise program for 24 weeks while the control group were asked not to participant in any extra exercise apart from their daily living activities. The G*power 3.1.2 program (Faul et al., 2009) was used to check statistical validity of results, the proper sample size was estimated given an effect size (ES) of 0.25, an α value of 0.05, and a desired statistical power (1-β) of 0.80. A minimum of 16 participants was needed according to the software's calculations. The final numbers of participants was 21(11 and 10 for the SEG; strength exercise group and CG; control group).

The purpose and the procedures of this study were explained in detail and informed consent of subjects was obtained before beginning the study. In addition, all participants completed a Physical Activity Readiness Questionnaire (PAR-Q & YOU) prior to the start of the experiment. All participants could walk by themselves, although some had discomfort in their daily lives. The study protocol was accepted by Institutional Review Board (IRB) of Pusan National University (PNUIRB/2014-31-HR). The physical characteristics of subjects in each group are described in Table 1.

2.2. Methods

Every measurement of height, weight, the volume of hippocampus and the senior fitness test was done before and 48 h after strength exercise of 24 weeks.

The height was measured at 10:00 a.m. three days before the program starts using a 2-m movable extensometer (CAS, HC-1500, Korea). The weight was measured on the same day using an electronic scale (CAS, DB-1(150A), Korea) while in a vertical position. Body mass index (BMI) was calculated from these measurements.

2.2.1. Magnetic resonance imaging (MRI)

Magnetic resonance imaging (MRI) scanning was conducted using a 3T Siemens Tim Trio (Siemens Healthcare, Erlangen, Germany). Coronal T1-weighted images were acquired using MP-RAGE (magnetization-prepared rapidly acquired gradient echo) sequences. Imaging was performed using Pusan National University Hospital's standard protocols (TR (repetition time) 1800 ms, TE (echo time) 2.1 ms, FOV 250 × 250, FA (flip angle) 9, slice thickness 1.0 mm, phase encoding gradient 256,

Table 1
Physical characteristics of subjects in each group of older women.

Variable Group	Age (yrs)	Body-height (cm)	Body-weight (kg)	BMI (kg/m^2)
SEG ($n = 11$)	76.10 ± 3.85	151.14 ± 5.42	54.74 ± 6.73	23.96 ± 2.70
CG ($n = 10$)	76.40 ± 3.27	152.77 ± 5.63	52.35 ± 2.86	22.50 ± 1.88
t-Value	0.197^{NS}	0.673^{NS}	1.041^{NS}	1.425^{NS}

SEG: strength exercise group.
CG: control group.
NS: non-significant.