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Effects of Exercise on Cognitive Function Improvement in South Korean Elderly: A Meta-Analysis

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Abstract

The purpose of this study was to conduct a meta-analysis and investigate the impact of exercise on cognitive function in elderly individuals in South Korea. To achieve this goal, academic journals published in South Korea between January 2012 and August 2022 were analyzed comprehensively. The study selected 34 final studies and used the CMA 2.0 for meta-analysis. First, the overall effect size of exercise intervention was found to be significantly large (ES = 1.138). Second, gender and age were not statistically significant to explain effect size of exercise intervention. Third, the study found that a 16-week intervention period had the greatest effect (ES = 2.700). Lastly, the effect size of exercise intervention increased with the passage of time (p=.008). In conclusion, the study found that exercise participation among elderly individuals had a positive impact on cognitive function improvement. The effect of exercise increased with the passage of time.

Key words: meta-analysis, elderly, cognitive function improvement, exercise

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Introduction

Around the 1970s, the world recognized the status of the aging population and tried to construct a plan, centering on the UN, to respond to the problems this causes. The UN classifies an aging society as when the population aged ≥65 years accounts for 7% of the total population, an aged society when they account for >14%, and a super-aged society when they account for >20% (Shin, 2019).

The Organization for Economic Development and Cooperation (OECD) and a UN report mentioned that South Korea is the most rapidly aging country, and predicts that it will become a super-aged society just 26 years after becoming an aging society in 2000. Looking at the life table of the National Statistical Office, the life expectancy in South Korea as of 2020 is 80.5 years for men and 86.5 years for women, with an average of 83.5 years. The OECD average is 3.0 years old, which is the second highest among member countries after Japan's 84.7 years old. As a result of the population's rapid aging and the increase in life expectancy, the number of people with dementia—a representative elderly disease—is also increasing every year. This is also one of the countries where the number of dementia patients is increasing the fastest around the world.

In the case of the elderly, along with the deterioration of physical function, interpersonal relationships, depression, sense of isolation, and cognitive function gradually deteriorate. Among them, cognitive functions are all processes of perception, judgment, and execution that occur in the brain, and are treated as essential elements for successful aging (Kwon, Kang, 2021). In addition, cognitive function refers to the ability to understand situations occurring during daily life, the ability to make decisions accordingly, and the ability to adapt to the environment (Lee, 2022). However, the decline in cognitive function due to aging cannot be the result of uniformly following all. In some elderly people, cognitive decline occurs at an early stage, and there are cases where there is little change (Studenski et al., 2011).

In the study of Baik (2015), a longitudinal analysis was conducted on the factors that change the cognitive function of the elderly. The higher the level of education, the slower the decline in cognitive function, and the higher the initial value of depressive symptoms, the lower the cognitive function. In addition, the decline in cognitive function was faster as the activities of daily living(ADL) were poor. In other words, it was found that cognitive decline can be delayed if daily living activity skills are improved, and that various exercise programs have a significant effect on ADL (Kim, Lee, & Park, 2015).

Previous research has shown that people who engage in regular physical activity show cognitive decline 2–5 years later than those who don't (Bherer, Erickson, & Liu-Ambrose, 2013). In addition, as a result of tracking physical activity among the elderly for 2–10 years, it was found that functional decline in various cognitive areas (working memory, processing speed, attention, and general mental function) was found six years later than in the inactive elderly (Barnes, Yaffe, Satariano, & Tager, 2003). As a result of analyzing the correlation between past or present physical activity and cognitive function in 9,344 women older than 65 years, those who were physically active during adolescence or who engaged in regular physical activity showed slower cognitive decline than those who did not (Middleton, Barnes, Lui, & Yaffe, 2010).

Exercise is generally considered to help improve physical and mental health, but the evaluation of its effect on cognitive function remains unclear (Tseng, Gau, & Lou, 2011). Therefore, this study aims to objectively investigate the effect of exercise participation on cognitive function among the elderly in South Korea through meta-analysis. Meta-analysis is the statistical analysis of collected research data to unify the results of individual studies (Glass & Smith, 1979). This study examines the effect of exercise on improving cognitive function in the elderly in South Korea and to help improve the quality of physical activity programs for dementia prevention.

Methods

Study Selection Criteria

To comprehensively analyze the effects of exercise participation among the elderly on cognitive function, academic journals published in South Korea in January 2012–August 2022 were included for analysis. The scope of the more specific analysis target for meta-analysis was set as follows.

First, study participants were limited to those aged ≥65 years.

Second, only intervention studies in which exercise was set as an independent variable and cognitive function as a dependent variable were targeted.

Third, various measurement tools were used for cognitive function considered a dependent variable in this study. However, since each measurement tool has different contents and characteristics, the reliability of the analysis results for this study could suffer if they are all used(Allen & Meyer, 1990). Therefore, it was decided to include only studies that used the Mini-Mental State Examination, MMSE(Folstein, Robins, & Helzer, 1983) as a tool to measure cognitive function.

Fourth, qualitative research and causal relationship verification—not intervention studies—were excluded even if they included movement and cognitive function.

Fifth, it was limited to academic journals recognized by the National Research Foundation of Korea.

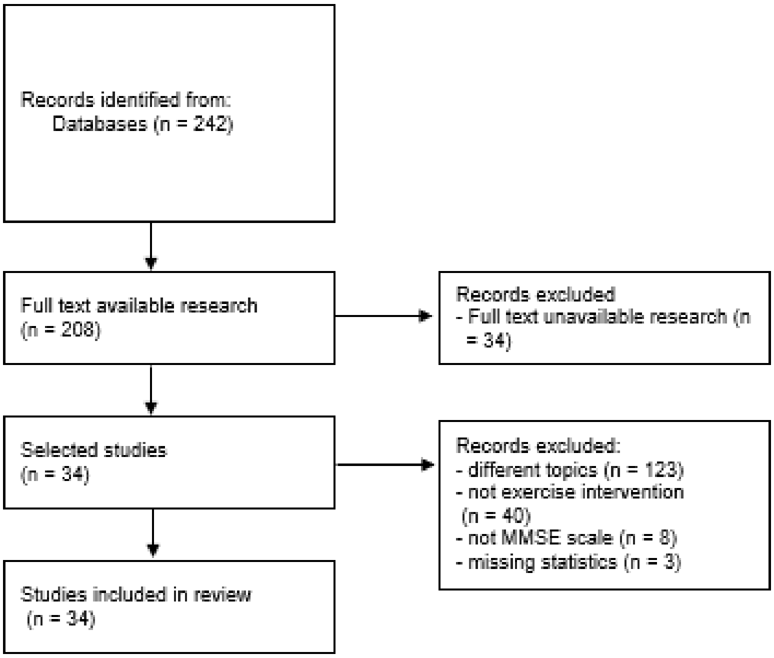


Figure 1. PRISMA flowchart

Search Methods for Analytical Studies

The search for academic journals published in South Korea encompassed the academic research information service (http://www.riss.kr), Korean academic information (http://kiss.kstudy.com), and the National Assembly Electronic Library (http://dl.nanet.go.kr)'s database. In the search, 242 studies were searched through keywords such as the elderly, exercise, and cognitive function; among them, 34 studies were finally selected, excluding those that did not meet the selection criteria.

Data Coding

The final 34 studies were conducted jointly by the authors of this study and the mean, standard deviation, sample size, and t-value of the intervention and control groups were coded “before” and “after.” In addition, to suggest effective intervention methods, gender, age, intervention period, number of interventions, and publication year were additionally used as control variables.

Data Processing

A meta-analysis was performed using the Comprehensive Meta-Analysis (CMA) 2.0 program to derive research results based on the research material to be analyzed. The pre–post mean difference of the exercise intervention to examine the cognitive function change was calculated as the standardized mean difference (Cohen's d) value. However, since the effect size can be overestimated for a small number of samples (Hedges & Olkin, 2014), it was converted to the mean difference value corrected by Hedges' g. Furthermore, when judging a fixed effect model and a random effect model, heterogeneity verification using I^2 can be performed but this should be avoided. This is because the choice of research model must take into account the nature and environment of each study as well as the study participants (Borenstein, Hedges, Higgins, & Rothstein, 2021). In other words, it is preferable to use a random effect model because there is inter-study variance. In addition, meta-regression analysis and meta-ANOVA analysis were performed to analyze the moderating effect depending on the intervention method.

Results

Total Size Effect of the Exercise Intervention

In total, 34 studies were used to verify the effectiveness of exercise intervention on changes in cognitive function among the elderly; <Table 1> and <Figure 2> shows the results of deriving the overall effect size. The effect size of 1.138 was derived through a random effect model, assuming that variance exists because the characteristics in each study are different. According to Cohen(1988), if the degree of effect size is .2, .5, or .8, it is considered a small, median, or large effect size, respectively. Therefore, it can be said that exercise intervention for the elderly has a very large effect on the improvement of cognitive function.

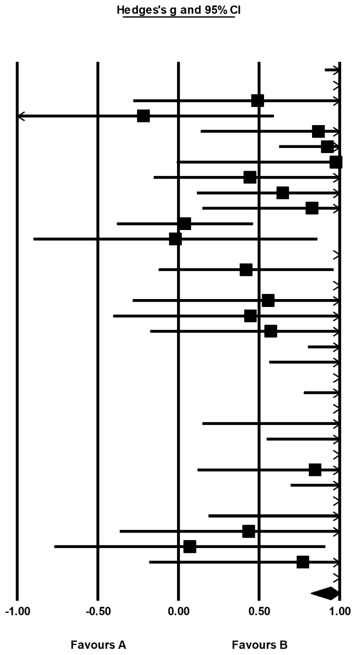
Table 1. Total size effect of the exercise intervention

Model	k	ES	-95%CI	+95%CI	Q
random effect model	34	1.138	.872	1.404	141.744***

*** $p < 0.001$.

Meta Analysis

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
1. Han el al., (2014)	1.826	0.467	0.218	0.910	2.742	3.906	0.000
2. Kim et al., (2018)	2.726	0.500	0.250	1.746	3.706	5.451	0.000
3. Jin et al., (2017)	0.491	0.393	0.155	-0.280	1.262	1.248	0.212
4. Song et al., (2016)	-0.216	0.412	0.169	-1.023	0.590	-0.526	0.599
5. Kwack et al., (2022)	0.869	0.373	0.139	0.139	1.599	2.333	0.020
6. Ahn (2019)	0.924	0.153	0.023	0.624	1.223	6.045	0.000
7. Lee (2015)	0.977	0.503	0.253	-0.009	1.964	1.941	0.052
8. Lee et al., (2021)	0.444	0.304	0.092	-0.152	1.039	1.460	0.144
9. Kim et al., (2012)	0.647	0.271	0.074	0.115	1.178	2.385	0.017
10. Jung et al., (2013)	0.828	0.346	0.120	0.150	1.506	2.393	0.017
11. Kwon et al., (2014)	0.040	0.215	0.046	-0.381	0.461	0.187	0.852
12. Choi (2012)	-0.019	0.449	0.202	-0.899	0.861	-0.043	0.966
13. Lee et al., (2021)	3.565	0.581	0.338	2.425	4.704	6.131	0.000
14. Hyun et al., (2020)	0.420	0.276	0.076	-0.122	0.961	1.518	0.129
15. Eom et al., (2021)	1.962	0.485	0.236	1.010	2.913	4.042	0.000
16. Jang et al., (2021)	0.557	0.428	0.183	-0.283	1.396	1.300	0.194
17. Kim et al., (2012)	0.447	0.434	0.188	-0.404	1.297	1.029	0.304
18. Lee et al., (2012)	0.573	0.382	0.146	-0.175	1.321	1.502	0.133
19. Kim et al., (2013)	1.611	0.412	0.169	0.804	2.418	3.913	0.000
20. Park et al., (2022)	1.352	0.402	0.162	0.563	2.140	3.358	0.001
21. Na et al., (2016)	2.622	0.570	0.325	1.505	3.739	4.603	0.000
22. Choi et al., (2013)	1.323	0.278	0.077	0.779	1.867	4.765	0.000
23. Kim et al., (2020)	3.321	0.647	0.419	2.053	4.590	5.131	0.000
24. Song et al., (2018)	1.231	0.552	0.305	0.150	2.313	2.231	0.026
25. Kim et al., (2019)	1.366	0.417	0.174	0.548	2.183	3.273	0.001
26. Yeon et al., (2017)	2.432	0.528	0.279	1.398	3.467	4.608	0.000
27. Lee et al., (2018)	0.848	0.372	0.138	0.119	1.576	2.280	0.023
28. Hong (2012)	1.573	0.447	0.200	0.696	2.449	3.517	0.000
29. Song et al., (2021)	2.358	0.597	0.356	1.188	3.527	3.952	0.000
30. Jung et al., (2019)	1.070	0.451	0.203	0.187	1.954	2.374	0.018
31. Kim et al., (2016)	0.435	0.407	0.166	-0.363	1.234	1.068	0.285
32. Ha et al., (2017)	0.070	0.428	0.184	-0.769	0.910	0.164	0.870
33. Jung et al., (2019)	0.772	0.486	0.236	-0.181	1.725	1.588	0.112
34. Ahn et al., (2019)	2.062	0.397	0.158	1.283	2.841	5.189	0.000
	0.943	0.062	0.004	0.821	1.065	15.126	0.000



Meta Analysis

Figure 2. Meta-analysis of individual effect sizes

Exercise Intervention Effect Size by Gender

<Table 2> and <Figure 1> are the results of a meta-regression analysis in which the male ratio was set as a control variable to investigate the change in the effect size of exercise intervention depending on the gender of the elderly. Therefore, the slope coefficient was -.001, but it was not statistically significant (p = .688). In other words, the effect of exercise interventions on cognitive function evidently does not differ between genders.

Table 2. Exercise intervention effect size by gender

	Estimate	SE	-95%CI	+95%CI	z-value	p-value
slope	-.00121	.00302	-.00714	.00471	-.40134	.68817
intercept	.94657	.07903	.79167	1.10146	11.97744	.00000

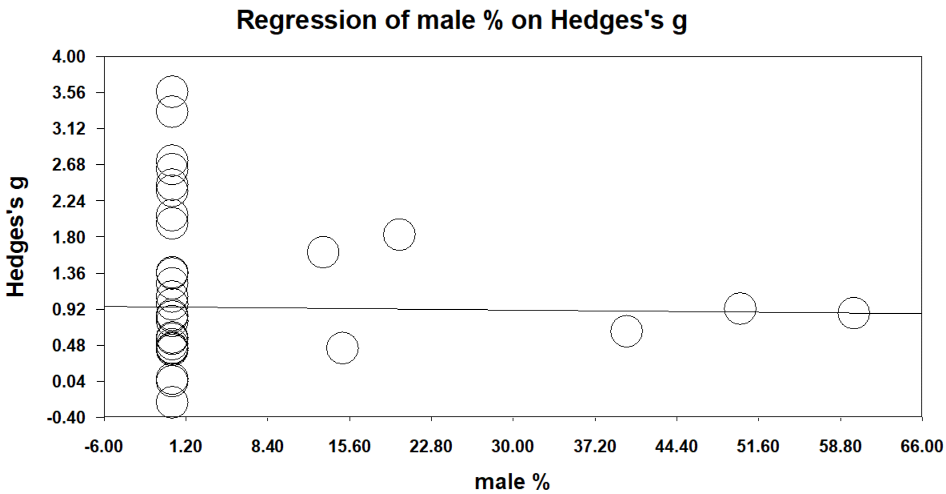


Figure 3. Exercise intervention effect size by gender

Effect Size of Exercise Intervention according to Age

<Table 3> and <Figure 2> show the results of meta-regression analysis by setting age as the controlling variable to determine what changes the effect size of exercise intervention shows depending on the age of the elderly participants. Accordingly, the slope coefficient was .003, which was not statistically significant (p = .826).

In other words, the influence of exercise interventions on cognitive function evidently does not differ depending on age.

Table 3. Effect size of exercise intervention according to age

	Estimate	SE	-95%CI	+95%CI	z-value	p-value
slope	.00347	.01576	-.02742	.03437	.22042	.82554
intercept	.63909	1.18219	-1.67797	2.95615	.54060	.58878

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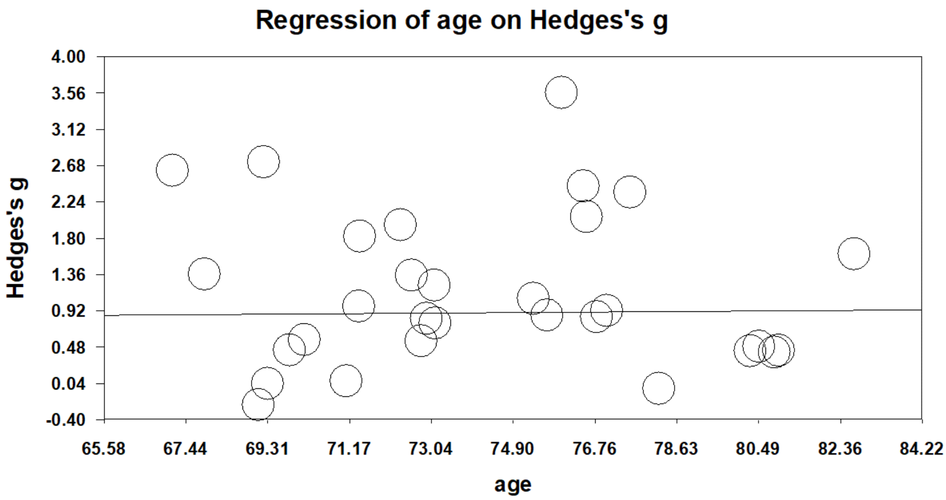

Figure 4. Effect size of exercise intervention according to age

Effect Size of Exercise Intervention Depending on the Intervention Duration

<Table 4> shows the results of meta-ANOVA with the intervention period as the controlling variable to examine the changes in the effect size of exercise for intervention depending on the intervention period for the elderly. As a result, for the most effective intervention period for the elderly, 16 weeks of intervention (ES = 2.700) showed the largest effect size, and there was a significant difference depending on the intervention period (p = .013).

Table 4. Effect size of exercise intervention depending on the intervention duration

weeks	k	ES	SE	-95%CI	+95%CI	Q	I2	Qb(df)
12	25	1.136	.146	.850	1.422	83.514	71.262	12.665(4) p=.013
16	2	2.700	.539	1.644	3.756	4.550	78.023	
24	3	.706	.417	-.111	1.523	7.732	74.133	
4	2	.333	.450	-.550	1.216	3.077	67.497	
8	2	1.200	.507	.207	2.194	1.461	31.571	

Effect size of exercise intervention according to publication year

<Table 5> and <Figure 3> shows the results of meta-ANOVA with the intervention period as the con-trolling variable to examine the changes in the effect size of exercise for intervention de-pending on the publication year for the elderly. The slope coefficient was statistically significant

at .050 (p=.008). It can be seen that the impact of motor interventions on cognitive function is increasing over time.

Table 5. Effect size of exercise intervention according to publication year

	Estimate	SE	-95%CI	+95%CI	z-value	p-value
slope	.05029	.01904	.01297	.08761	2.64133	.00826
intercept	-100.49310	38.40342	-175.76242	-25.22378	-2.61677	.00888

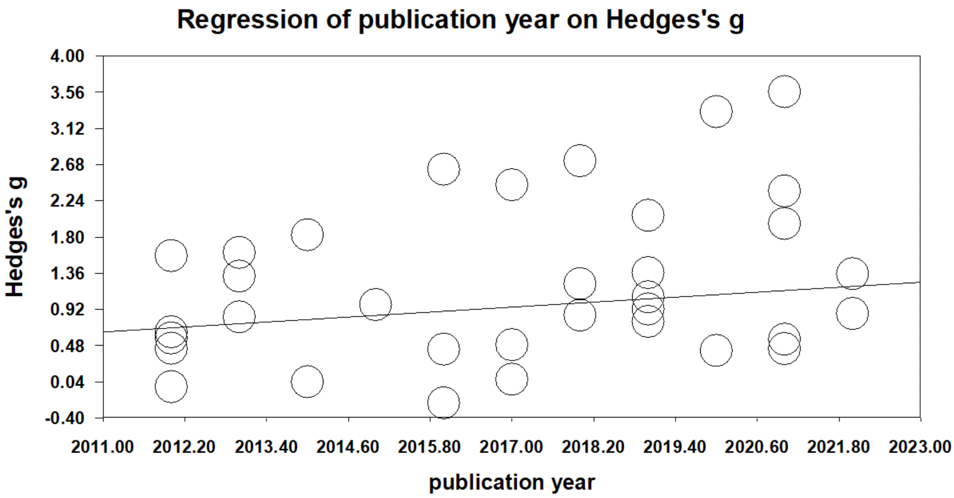

Figure 5. Effect size of exercise intervention according to publication year

Publication bias Validation

Studies that do not show statistical significance are relatively less likely to be published than studies with significant results. In this case, if the research results are biased to one side, a reliability problem can emerge. Accordingly, it must be visually confirmed through Funnel Plots and can be statistically verified through Egger's regression analysis. As a result, the intercept was 2.858, the standard error was .920, and p = .004, indicating that there was publication bias. Accordingly, <Figure 4> shows the results of applying the trim-and-fill of Duval & Tweedie (2000) to correct the asymmetry of publication bias. When seven studies were added, the effect size was .761, which was decreased from the effect size before correction, which was .943.

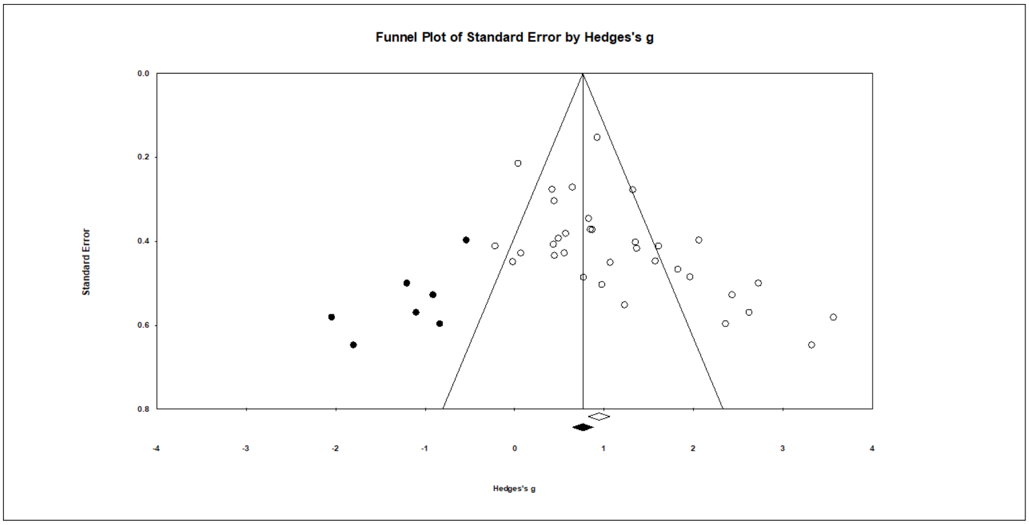

Figure 6. Funnel plot

Discussion

The rapid aging of the population is causing serious social problems and is recognized as the most fundamental cause of the challenges facing all sectors, including the economy, society, and health. In addition, as life expectancy increases, many changes are required in individuals' lives. In particular, interest is growing in mental health and cognitive function. Therefore, this study investigates the effect of exercise participation among the elderly on cognitive function improvement through meta-analysis. Among domestic studies conducted January 2012–August 2022, 34 studies using MMSE (Hedges & Olkin, 2014), a tool for measuring motor and cognitive functions, were selected and analyzed. The specific discussion is as follows.

First, as a result of calculating the overall effect size of exercise intervention, it showed a very large effect (ES = 1.138). Cohen (1988) found that the overall effect was significantly greater when it was about .8. In this study, it was significantly larger than .8, indicating that exercise intervention among the elderly had a very large effect on cognitive function improvement. Previous studies have shown that a regular exercise program can prevent cognitive decline due to aging and improve cognitive function through improved cardiorespiratory health and increased physical activity (Colcombe et al., 2004; Kramer & Willis, 2002; McAuley, Kramer, & Colcombe, 2004; Young, Angevaren, Rusted, & Tabet, 2015). In addition, it is clear that exercise has a positive effect on cognitive function, which may be due to physiological adaptation through increased physical strength (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008). This result, which can be predicted from previous studies, suggests that improving the lives and physical activity of the elderly in South Korea will have a positive effect on their cognitive ability.

Second, examining the effect size of exercise intervention stratified by gender and age revealed that it was not statistically significant. Considering the studies used in this study's analysis, most were limited to elderly women, and the age group was not subdivided into those ≥65 years old. That is, few studies have analyzed the effect of exercise stratified by gender and age group. Therefore, more research should be done on the implementation of exercise programs by segmenting gender and age for those ≥65 years old.

Third, as a result of examining the effect size of exercise intervention depending on the intervention period, a 16-week intervention period showed the greatest effect (ES = 2.700). The studies used in this meta-analysis were conducted by setting the exercise period at 8–24 weeks; it was confirmed that the 16-week intervention period had the greatest effect on cognitive function improvement.

Fourth, as a result of examining the effect size of exercise intervention depending on the passage of time, it is clearly increasing with the passage of time ($p=.008$). As such, regular exercise for the elderly has been established as an essential element of maintaining a healthy life. Social integration networks, cognitive leisure activities, and regular physical activity play an important role in dementia prevention, and among them, physical activity plays the biggest role in maintaining health and cognitive function (Fratiglioni, Wang, Ericsson, Maytan, & Winblad, 2000). As a subcategory of physical activity, exercise is planned and organized to improve particular bodily functions or stamina. Seniors are encouraged to engage in regular exercise for their physical and cognitive health. This study presents various exercise programs for improving cognitive function such as aerobic exercise, fine muscle exercise, walking with correct posture, band exercise, and water exercise. This means that the value of exercise is a recognized dementia-prevention method.

Conclusions and Suggestions

This study investigates the effect of elderly exercise participation on cognitive function improvement for the prevention of dementia—a disease that primarily affects the elderly—using meta-analysis. The effect of exercise intervention on cognitive function improvement was large and there was no statistical significance for either gender or age. In addition, when examining the effective exercise period, the 16-week intervention period showed the greatest effect. The effect size depending on the publication year increased with the passage of time, indicating that interest in exercise for cognitive function is increasing. Based on the results of this study, suggestions for follow-up research are as follows.

In this study, the cognitive function measurement tool was limited to MMSE to derive results on the effectiveness of exercise. Therefore, follow-up studies should expand the scope of the measurement tool and propose research results. In addition, it is necessary to verify the effectiveness of cognitive function improvement depending on the type of exercise; this will help quantitatively improve the development of various physical activities and exercise programs and improve the quality of dementia-prevention exercise programs.

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