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Changes in physical activity and cognitive decline in older adults living in the community

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Abstract Accumulating evidence suggests that physical activity may be beneficial in preserving cognition in late life. This study examined the association between baseline and changes in physical activity and cognitive decline in community-dwelling older people. Data were from the Korean Longitudinal Study of Aging, with 2605 aged 65 years and older subjects interviewed in 2006 and followed up for 2 years. Cognitive decline was defined by calculating the Reliable Change Index using the Mini-Mental State Examination. Physical activity levels were categorized as sedentary, low, or high. Changes in physical activity were classified as inactive, decreaser, increaser, or active. Logistic regression analysis of baseline and changes in physical activity with cognitive decline was performed. Compared with the sedentary group at baseline, both the low and high activity groups were less likely to experience cognitive decline. The active (odds ratio [OR]=0.40, 95 % confidence interval [CI] 0.23–0.68) and increaser (OR=0.45, 95 % CI 0.27–0.74) group, compared with the inactive counterpart, demonstrated a significantly lower likelihood of cognitive decline. Older adults who remained active or increased activity over time had a reduced risk of cognitive decline. Engagement in physical activity in late life may have cognitive health benefits.

Keywords Exercise · Cognition · Aged · Longitudinal studies

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Introduction

Cognitive decline is a common phenomenon in later life, with its rate increasing with age (Park et al. 2003). Declines in cognitive function are associated with an increased risk of frailty (Mitnitski et al. 2011), physical disability (Lee et al. 2005; Yaffe et al. 2010), poor quality of life or well-being (Bárrios et al. 2013; Wilson et al. 2013), and mortality (Lavery et al. 2009; Park et al. 2013; Yaffe et al. 2010). Cognitive decline is also predictive of incident dementia (Hensel et al. 2009).

Accumulating evidence on modifiable risk factors of cognitive decline indicates the potential benefit of physical activity on maintaining cognitive function in late life (Lee et al. 2010b; Plassman et al. 2010). Population-based studies of older adults have reported a slower rate of decline in cognitive function among those engaged in higher levels of physical activity at baseline (Ku et al.

2012; Lytle et al. 2004; Weuve et al. 2004; Yaffe et al. 2001). In a meta-analysis of prospective studies involving people aged 65 years and older, physical activity at both high and low-to-moderate levels was found to lower the risk of cognitive decline (Sofi et al. 2011). In addition, physical exercise training of older adults has shown some promise in enhancing cognitive vitality (Colcombe and Kramer 2003; Kirk-Sanchez and McGough 2014).

However, many prospective observational studies examining the relationship between physical activity and cognitive change are limited by single baseline measurement of physical activity (Ku et al. 2012). Physical activity, even in late life, is known to change, with a number of older people remaining active or increasing their levels of activity over time (Martinson et al. 2003; Xue et al. 2012). A systematic review of the global trends in physical activity in the older population found an increasing participation in leisure-time physical activity among developed countries (Sun et al. 2013). Examining whether a maintained or increased physical activity over time is associated with a reduced risk of cognitive decline would have important clinical and public health implications for promoting an active lifestyle for older people.

Aims of the study

In this study, we examine the association between physical activity and cognitive decline in a national sample of older people living in the community. We hypothesize that those who engage in physical activity, compared with those who are sedentary, at baseline are less likely to experience cognitive decline. Moreover, we test the hypothesis that maintaining or increasing physical activity over time is associated with a reduced risk of cognitive decline.

Materials and methods

Data source

Data from the Korean Longitudinal Study on Aging (KLoSA) were used in the study (Korea Labor Institute 2010; Lee et al. 2010a). KLoSA is a public-use dataset (http://survey.keis.or.kr/). The baseline population consisted of a nationally representative sample of community-dwelling people aged 45 years and older in the Republic of Korea in 2006, selected using multistage stratified cluster sampling. Computer-assisted personal interviews were conducted by trained interviewers during household visits, after written informed consents were obtained from the individual respondents. Among the 10,254 who completed the baseline survey (89.2 % response rate), we used data for those aged 65 years and older (n=4165). At 2-year follow-up in 2008, 3511 (84.3 %) completed the interview, with 208 deceased and 446 lost to follow-up. Although the deceased tended to be older and more disabled, compared with the respondents, others who were lost to follow-up did not differ significantly in age, comorbidity, physical disability, depressive symptoms, or cognitive function. Proxy response (n=412) on the Korean version of the Mini-Mental State Examination (K-MMSE) was excluded. The final analytical sample consisted of 2605, after further excluding those cognitively impaired at baseline, defined as scoring more than 2 SD below the mean of age- and education-defined strata on the K-MMSE (Lee et al. 2010a).

Measurement

Cognitive function was assessed using the validated K-MMSE (Folstein et al. 1975; Kang et al. 1997). We used the Reliable Change Index (RCI) to define a significant deterioration in cognitive function adjusting for measurement error and practice effects (Chelune et al. 1993). RCI was calculated by $[(X_2-X_1)-(M_2-M_1)]/\text{SED}$, where X_1 is the observed pretest score, X_2 is the observed posttest score, M_1 is the group mean pretest score, M_2 is the group mean posttest score, and SED is the standard error of a difference. SED is $\text{SD}_1\times 2^{1/2}\times(1-r_{xx})^{1/2}$, where r_{xx} is the test–retest reliability and SD_1 is the standard deviation of the pretest score. A test reliability value of 0.86 was used, based on a 4-week test–retest reliability from a study of community-dwelling older Korean adults (Kim et al. 1999). RCI values less than −1.645 (one-tailed) were defined as cognitive decline. An RCI that corrected for practice or aging effects has been reported to accurately classify cognitive changes in older people (Frerichs and Tuokko 2005).

Physical activity was assessed by asking whether the subjects participated in any type of exercise at least once a week, and if the response was positive, the frequency and duration of exercise were recorded. Levels of physical activity were categorized into three groups: sedentary, low, and high. Those who did not engage in any type of exercise were categorized as being sedentary (coded as 0). Low activity was defined as 1 to 149 min/week (coded as 1) and high activity as ≥150 min/week (coded as 2), according to the global recommendations on physical activity (World Health Organization 2010). Changes in physical activity between baseline and 2-year follow-up were classified into four categories: inactive (0 to 0), decreaser (2 to 1, 2 to 0, or 1 to 0), increaser (0 to 1, 0 to 2, or 1 to 2), or active (2 to 2 or 1 to 1).

Covariates known to be associated with cognitive function from previous studies (Lee et al. 2010a; Lee et al. 2010b) were selected. Sociodemographic characteristics included age, gender, education (6 years or less versus 7 years or more), and income (household equivalent income in quartiles). Lifestyle variables included smoking (current smoker versus non- or former smokers), alcohol consumption (heavy, defined as more than seven drinks per week or three drinks per occasion versus not heavy drinking) (National Institute on Alcohol Abuse and Alcoholism 2005), and body mass index (BMI, kg/m^2). Comorbidity was defined as the number of self-reported, physician-diagnosed chronic conditions (hypertension, heart disease, cerebrovascular disease, and diabetes mellitus). Disability was determined by the number of difficulty performing tasks in the seven-item activities of daily living (ADLs) and ten-item instrumental ADL (IADL) scales (Won et al. 2002). Depressive symptoms were assessed using the ten-item Center for Epidemiologic Studies Depression (CES-D) scale, with higher scores indicating more depressive symptoms (Andresen et al. 1994).

Statistical analysis

Sample characteristics by follow-up status were analyzed by Stuart–Maxwell or paired *t* tests. Frequencies and means of sample characteristics were analyzed by baseline physical activity and changes in physical activity levels over 2 years, using the chi-square test and analysis of variance. Percentages of cognitive decline were calculated according to baseline and changes in physical activity, and chi-square tests were used to detect significant differences. Both unadjusted and multivariable-adjusted (for age, gender, education, income, smoking, alcohol consumption, BMI, comorbidity, disability, and depressive symptoms) proportions of cognitive decline were derived. Except for gender and baseline cognitive function, all covariates were treated as time-dependent variables. Odds ratios and 95 % confidence intervals (CIs) were calculated with logistic regression models, using generalized estimating equations, to take into account autocorrelation of the responses to produce consistent estimates of the regression parameters and their variance (Liang and Zeger 1986). The dose–response relationship between physical activity and cognitive decline was examined using chi-square tests for trend. All analyses were performed using Stata 13.1 (StataCorp, College Station, TX), taking into account the complex sampling design.

Results

Sample characteristics

At baseline, the average age of the participants was 71.9 years (±6.6), 55.5 % were women, and 69.6 % had less than or equal to 6 years of education (Table 1). Of the respondents, 15.5 and 19.2 % were current smokers and heavy drinkers, respectively. During the 2-year follow-up, the proportion of current smokers and heavy drinkers tended to decrease. In the interval, there was an increase in comorbidity, number of disability, and depressive symptoms.

Slightly less than two thirds of the respondents had a sedentary lifestyle at baseline, with 8.4 and 26.6 %, respectively, engaging in low and high levels of physical activity. At 2-year follow-up, the proportion of those sedentary increased to 67.6 %. The average cognitive function score, measured by the K-MMSE, was 24.3 (±4.6) at baseline but declined to 23.0 (±6.1) at follow-up.

Baseline characteristics by physical activity

Those who engaged in a higher level of physical activity at baseline were characterized as being younger, men, and more highly educated (Table 2). They also tended to have slightly higher BMI, more comorbid conditions, less disability and depressive symptoms, and higher cognitive status.

During the 2-year follow-up, the majority (53.4 %) of the respondents remained sedentary (inactive), followed by the decreaser (16.6 %), active (16.1 %), and increaser

Table 1 Sample characteristics at baseline and follow-up: Korean Longitudinal Study of Aging 2006–2008 (weighted %, mean±SD) (n=2605)

Variable	Baseline (2006)	Follow-up (2008)
Age	71.9±6.6	73.9±6.7***
Women	55.5	55.5
Education ≤6 years	69.6	67.1***
Income, lowest quartile	23.7	25.5
Current smoking	15.5	14.4**
Heavy drinking[a]	19.2	15.5***
Body mass index (kg/m^2)	22.9±3.6	22.8±3.6
Comorbidity[b]	0.7±0.9	0.8±1.0***
ADL disability[c]	0.1±0.7	0.2±1.0***
IADL disability[c]	0.5±1.8	0.7±2.3***
Depressive symptoms[d]	7.5±6.3	8.6±6.8***
Physical activity levels[e]		
Sedentary	65.0	67.6***
Low	8.4	6.2
High	26.6	26.2
Cognitive function[f]	24.3±4.6	23.0±6.1***

**p<0.01; ***p<0.001 (Stuart–Maxwell test, paired t test)

[a] Alcohol consumption more than seven drinks per week or three drinks per occasion

[b] Number of chronic conditions (hypertension, heart disease, cerebrovascular disease, and diabetes mellitus)

[c] Number of difficulty in seven-item activities of daily living (ADLs) and ten-item instrumental ADL (IADLs)

[d] Number of symptoms in the ten-item Center for Epidemiologic Studies Depression (CES-D) scale, ranging from 0 to 30, with higher scores indicating more depressive symptoms

[e] Participation in exercise (min/week): sedentary (0), low (1–149), and high (≥150)

[f] Korean version of the Mini-Mental State Examination (K-MMSE), ranging from 0 to 30, with lower scores indicating poorer function

(13.9 %). Participants showing more positive changes in physical activity, that is, those who demonstrated higher levels of physical activity over time; tended to be younger, men, and heavy drinkers; and have higher BMI (Table 3). They also tended to manifest less disability, less depressive symptoms, and higher cognitive function. Among those who continued to be active at follow-up, about 90 % were engaged in high levels of physical activity at baseline. About four fifths of the increasers were sedentary at baseline, while the majority of the decreasers participated in high activity at baseline.

Cognitive decline by physical activity

The percentage of cognitive decline, defined by RCI, was 9.8 %, which corresponded to a 10.3 (±4.7) point decline in the K-MMSE over 2 years, equivalent to a five-point decline per year. Compared with those sedentary at baseline, the low and high activity groups exhibited lower proportions of cognitive decline (Fig. 1). There was significantly less cognitive decline among those who maintained or increased their physical activity levels, compared with those who remained sedentary, in the follow-up period.

Multivariable analysis

In the multiple logistic regression analysis of baseline physical activity, those who participated in either low or high physical activity had a 45 and 34 %, respectively, lower likelihood of cognitive decline (Table 4). For changes in physical activity, those who maintained or increased their level of physical activity over time had a significantly reduced odds of cognitive decline. Compared with the inactive group, the active and the increaser groups were 60 and 55 %, respectively, less likely to experience declines in cognitive function. There was a significant trend (p<0.001) toward a greater reduction in the risk of cognitive decline with positive changes in physical activity levels over time.

Discussion

In this study of community-dwelling older people, baseline physical activity was found to predict a 2-year cognitive decline. Those who engaged in both low and high levels of physical activity had a reduced odds of cognitive decline. In addition, changes in the physical activity level were significantly associated with cognitive decline during the 2-year interval.

In this study, after adjustment of covariates, not only a generally recommended level of physical activity of ≥150 min per week at baseline predicted a diminished 2-year risk of cognitive deterioration, but also the lesser degree of physical activity displayed significant reduction in the risk. Although a linear trend emerged between physical activity and cognitive decline, a reduced risk was not evident with more activity. The results are in agreement with findings from previous studies that have reported baseline physical activity to be a

Table 2 Baseline sample characteristics by baseline physical activity levels: Korean Longitudinal Study of Aging 2006–2008 (weighted %, mean±standard deviation)

	Sedentary (n=1690)	Low (n=218)	High (n=697)
Age (years)	72.4±6.9	71.5±6.3	71.0±5.9***
Women	60.5	52.7	44.3***
Education ≤6 years	80.0	52.1	50.8***
Income, lowest quartile	24.1	20.8	23.6
Current smoking	16.5	13.5	13.6
Heavy drinking[a]	17.8	21.8	21.7
Body mass index (kg/m^2)	22.7±3.7	23.2±3.4	23.2±3.4***
Comorbidity[b]	0.6±0.9	0.8±1.0	0.7±0.9**
ADL disability[c]	0.1±0.8	0.03±0.30	0.04±0.44***
IADL disability[c]	0.6±2.0	0.4±1.5	0.3±1.3***
Depressive symptoms[d]	8.0±6.5	7.2±6.1	6.3±5.6***
Cognitive function[e]	23.7±4.9	25.6±3.9	25.5±3.7***

Participation in exercise (min/week): sedentary (0), low (1–149), and high (≥150)

**p<0.01; ***p<0.001 (analysis of variance, chi-square test)

[a] Alcohol consumption more than seven drinks per week or three drinks per occasion

[b] Number of chronic conditions (hypertension, heart disease, cerebrovascular disease, and diabetes mellitus)

[c] Number of difficulty in seven-item activities of daily living (ADLs) and ten-item instrumental ADL (IADLs)

[d] Number of symptoms in the ten-item Center for Epidemiologic Studies Depression (CES-D) scale, ranging from 0 to 30, with higher scores indicating more depressive symptoms

[e] Korean version of the Mini-Mental State Examination (K-MMSE), ranging from 0 to 30, with lower scores indicating poorer function

significant predictor of cognitive function (Lytle et al. 2004; Middleton et al. 2008; Sofi et al. 2011; van Gelder et al. 2004; Weuve et al. 2004; Yaffe et al. 2001). In a Canadian study of older adults, high exercise, defined as ≥3 times/week of at least walking intensity, was associated with an increased probability of stable or improved cognition over 5 years (Middleton et al. 2008). A medium–low intensity physical activity also has been reported to be associated with less cognitive decline in elderly men (van Gelder et al. 2004). In community-dwelling people aged 65 years or older, ≥30-min duration of aerobic exercise at either high (≥5 times/week) or low (<5 times/week) frequency was significantly associated with a lower likelihood of a 2-year cognitive decline, defined as more than three-point decline in MMSE (Lytle et al. 2004). A recent meta-analysis of 15 prospective studies has reported both a high and low-to-moderate levels of exercise to be protective against cognitive decline, demonstrating a similarly reduced risk of 38 and 35 %, respectively (Sofi et al. 2011). A dose–response effect of physical activity was not found, which indicates that physical activity does not have to be engaged at a very high level to engender cognitive benefits. There may even be an upper limit beyond which extensive physical activity may not yield any added benefit. A study examining physical activity and dementia did not find a significantly reduced risk for those participating in over 5 h per week of exercise (Chang et al. 2010). Alternatively, the protective effect may be cumulative as higher levels of activity showed less cognitive decline in a study of women aged 70 years and older performing regular physical activity for 8 to 15 years (Weuve et al. 2004). Even in this study, however, walking at an easy pace ≥1.5 h/week was associated with a significantly better cognitive performance.

We found that the participants who maintained or increased their previous activity level over time, compared with those who continued to lead a sedentary lifestyle, were more likely to demonstrate a reduced odds of cognitive decline. The strength of the relationship between changes in physical activity and cognitive function was stronger than the association between baseline physical activity and cognitive decline. This gives support to both a stable and dynamic association between physical activity and cognitive change (Lindwall et al. 2012). Not only was a "stable"

Table 3 Baseline sample characteristics by changes in physical activity: Korean Longitudinal Study of Aging 2006–2008 (weighted %, mean±standard deviation)

	Inactive (n=1390)	Decreaser (n=433)	Increaser (n=363)	Active (n=419)
Age (years)	72.7±7.1	71.6±6.4	70.9±5.7	70.6±5.5***
Women	62.4	52.2	51.3	39.5***
Education ≤6 years	81.8	61.8	65.0	41.1***
Income, lowest quartile	23.5	25.6	25.4	20.9
Current smoking	16.8	13.6	15.1	13.4
Heavy drinking[a]	17.6	19.4	19.4	24.1*
Body mass index (kg/m^2)	22.5±3.7	23.0±3.6	23.5±3.3	23.4±3.3***
Comorbidity[b]	0.6±0.9	0.8±1.0	0.7±1.0	0.7±0.9
ADL disability[c]	0.15±0.89	0.03±0.33	0.05±0.52	0.04±0.50***
IADL disability[c]	0.70±2.10	0.37±1.33	0.32±1.38	0.32±1.37***
Depressive symptoms[d]	8.2±6.5	7.1±6.2	6.9±6.4	5.9±5.3***
Physical activity level				
Sedentary	100.0	0.0	83.5	0.0***
Low	0.0	26.6	16.5	10.3
High	0.0	73.4	0.0	89.7
Cognitive function[e]	23.4±4.9	25.1±4.0	25.0±4.5	25.9±3.4***

Inactive (0→0), decreaser (2→1/0, 1→0), increaser (0→1/2, 1→2), and active (2→2, 1→1), where physical activity levels are 0= sedentary, 1=low (1–149), and 2=high (≥150 min/week)

*p<0.05; ***p<0.001 (analysis of variance, chi-square test)

[a] Alcohol consumption more than seven drinks/week or three drinks/occasion

[b] Number of chronic conditions (hypertension, heart disease, cerebrovascular disease, and diabetes mellitus)

[c] Number of difficulty in seven-item activities of daily living (ADLs) and ten-item instrumental ADL (IADLs)

[d] Number of symptoms in the ten-item Center for Epidemiologic Studies Depression (CES-D) scale, ranging from 0 to 30, with higher scores indicating more depressive symptoms

[e] Korean version of the Mini-Mental State Examination (K-MMSE), ranging from 0 to 30, with lower scores indicating poorer function

engagement in physical activity at baseline predictive of a reduced likelihood of cognitive decline, but also positive "dynamic" changes in physical activity were associated with lesser deterioration in the general cognitive ability. In an 11-year follow-up study of a national sample of elderly Taiwanese, compared with physical activity at baseline (β=0.22), change in physical activity (β=0.36) was more strongly associated with cognitive performance, even after excluding subjects who displayed cognitive decline prior to baseline survey (Ku et al. 2012). In a Canadian study (Lindwall et al. 2012), change in physical activity, compared with baseline physical activity, was more strongly associated with cognition, exhibiting selective improvements in fluent domains of cognition such as working memory and reasoning. However, the cognitive benefit of positive changes in physical activity is far from conclusive. A notion of "preserved differentiation" has been proposed where the association between physical activity and cognition is due to the highly active person also having higher initial cognitive ability, with this advantage being sustained over time (Bielak et al. 2014). It has been noted, however, that even when prior cognitive ability was adjusted, greater physical activity remained significantly associated with less cognitive decline (Gow et al. 2012b).

Considering that physical activity is a modifiable risk factor, with many older people remaining active or engaging in increasing levels of activity over time (Martinson et al. 2003; Xue et al. 2012), clinical and public health implications are evident. Even in late life, continuing to participate in physical exercise might confer some cognitive benefits. The finding of a less deterioration in cognitive function among those who increased their physical activity level over time supports promoting a more active lifestyle in old age. Clinicians

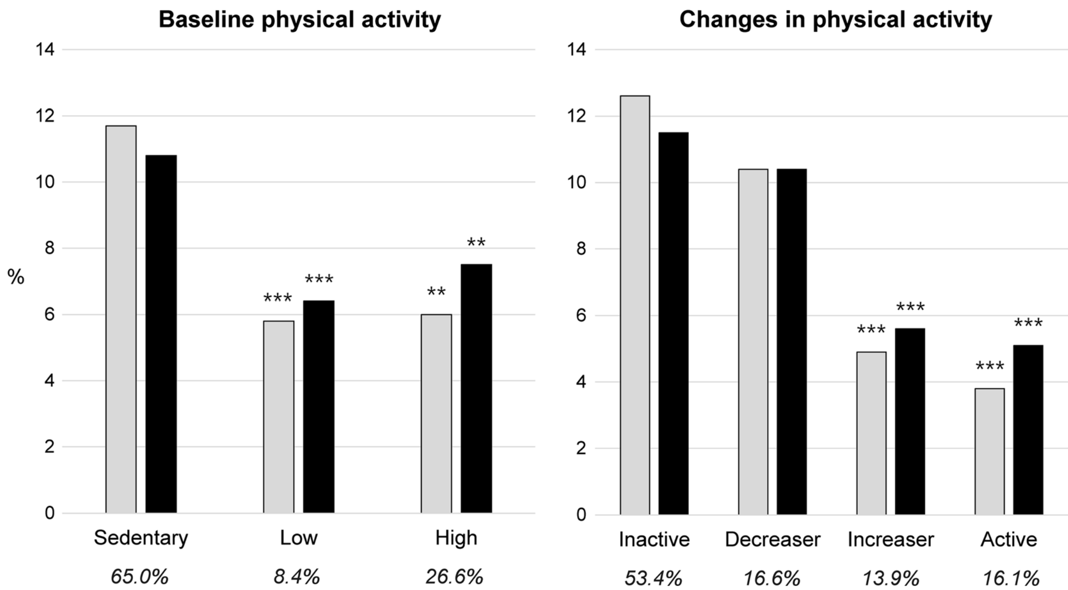

Fig. 1 Cognitive decline (weighted %) by baseline and changes in the physical activity level. Unadjusted (*shaded bars*) and multivariable (age, gender, education, income, smoking, alcohol consumption, body mass index, comorbidity, disability, and depressive symptoms) adjusted (*filled bars*). **$p<0.01$; ***$p<0.001$ ("sedentary" or "inactive" as the reference group)

need to assess older people's level of physical activity and inform them about the benefits that physical training can have on cognitive function (Colcombe and Kramer 2003). Alternatively, continued sedentariness or decreased physical activity levels may serve as a warning sign to check for cognitive decline, as a decrease in

Table 4 Odds ratios (95 % confidence interval) of cognitive decline by baseline and changes in physical activity: Korean Longitudinal Study of Aging 2006–2008 (n=2605)

Physical activity	Weighted %	Unadjusted	Adjusted[b]
Baseline			
Sedentary	65.0	1.00	1.00
Low	8.4	0.46 (0.30, 0.72)*	0.55 (0.35, 0.87)*
High	26.6	0.48 (0.36, 0.63)***	0.66 (0.50, 0.88)**
P_{trend}[c]		<0.001	0.002
Change[a]			
Inactive	53.4	1.00	1.00
Decreaser	16.6	0.80 (0.57, 1.13)	0.89 (0.63, 1.26)
Increaser	13.9	0.36 (0.22, 0.59)***	0.45 (0.27, 0.74)**
Active	16.1	0.27 (0.16, 0.46)***	0.40 (0.23, 0.68)**
P_{trend}[c]		<0.001	<0.001

Less than −1.645 (90 % confidence interval) on the Reliable Change Index of the Korean version of the Mini-Mental State Examination (K-MMSE)

*$p<0.05$; **$p<0.01$; ***$p<0.001$

[a] Inactive (0→0), decreaser (2→1/0, 1→0), increaser (0→1/2, 1→2), and active (2→2, 1→1), where physical activity levels are 0= sedentary, 1=low (1–149 min/week), and 2=high (≥150 min/week)

[b] Adjusted for gender and baseline cognitive function, with age, education, income, smoking, alcohol consumption, body mass index, comorbidity, disability, and depressive symptoms entered as time-dependent variables, using generalized estimating equations

[c] Chi-square test for linear trend

intensity or duration of physical activity (van Gelder et al. 2004) or reduction in daily activities (Mackinnon et al. 2003) in late life raises the risk of cognitive decline.

Multiple mechanisms are likely at work where physical activity might enhance cognitive performance in elderly people. Physical exercise-mediated increase in brain-derived neutrophic factors and cerebral blood flow and a decrease in abnormal protein deposition and systemic inflammation may moderate neurodegenerative changes (Kirk-Sanchez and McGough 2014). In animal models, exercise has been identified to promote neuroplasticity by enhancing neurogenesis, synaptogenesis, and angiogenesis (Hötting and Röder 2013). Using brain imaging techniques in humans, both functional and structural changes induced by physical training involving aerobic, resistance, and coordinative exercise have been demonstrated (Voelcker-Rehage and Niemann 2013). An indirect way in which exercise may be beneficial is by lowering vascular and metabolic risk factors, such as hypertension, type 2 diabetes, insulin resistance, and dyslipidemia, known to be associated with cognitive decline and impairment (Kirk-Sanchez and McGough 2014). Other health benefits of exercise such as reduction of chronic stress on the brain or engagement in other healthy lifestyles by those who are physically active may also indirectly lower the risk of cognitive decline (van Gelder et al. 2004).

One of the strengths of this study is the use of data from a nationally representative sample of older people in South Korea, giving support to the generalizability of the findings. The use of the RCI to assess change in cognitive function has enabled measurement of accurate and reliable change in cognitive status (Stein et al. 2012). This has reduced measurement error and testing effects of the screening instrument that often hinder diagnosis of true cognitive change (Hensel et al. 2009; Stein et al. 2012). Adjustment of multiple health-related potential confounders adds further credence to the observed significant findings.

There are, however, several limitations that need to be accounted for in interpreting the results. First, only a global measure of cognition was used in this study. There is a need to examine multiple cognitive domains, as recent studies have reported differential effects of physical activity on crystallized and fluid abilities (Bielak et al. 2014; Lindwall et al. 2012). Second, physical activity was self-reported and, thus, subject to bias. Although moderate correlations between subjective and objective measures of physical activity have been reported (Kowalski et al. 2012), use of objective measures would help to address variability and various components of physical activity across time. Third, attrition needs to be taken into consideration, although we did not find any significant difference in baseline cognitive function between the respondent and those lost to follow-up, excluding the deceased. Because people who dropped out tend to be at higher risk for cognitive decline, the magnitude of the association is likely to have been diminished. Finally, although we examined longitudinal association of both baseline and change in physical activity with cognitive decline, reverse causality cannot be ruled out due to the short period of follow-up. In this study, we excluded those cognitively impaired at baseline, who would be limited in physical activity due to their proclivity to cognitive deterioration prior to the study. It has been reported that among the various leisure activities, physical activity is less prone to reverse causation in its relation to cognitive function (Gow et al. 2012a; Richards et al. 2003).

In this study of community-dwelling older adults, those who practiced low to high levels of physical exercise, compared with the sedentary group, demonstrated a reduced risk of cognitive decline. Further, positive changes in physical activity over 2 years were significantly associated with less deterioration in cognitive function. There may be potential cognitive benefits of staying physically active in later years.

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