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Differential associations of physical job demands with cognitive impairment in Korean workers aged 45 and older: a 14-year longitudinal study using the Korean Longitudinal Study of Aging (KLoSA)

Jea Chul Ha ,[1,2] Jin-Ha Yoon [1,3]

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[1]Department of Public Health, Yonsei University Graduate School, Seoul, Republic of Korea
[2]Occupational and Environmental Medicine, Keimyung University College of Medicine, Daegu, Republic of Korea
[3]Preventive Medicine, Yonsei University College of Medicine, Seoul, Republic of Korea

Correspondence to
Professor Jin-Ha Yoon;
flyinyou@gmail.com

ABSTRACT

Objectives To investigate the association between subelements of physical job demands and cognitive impairment risk in middle-aged and older workers in Korea.

Design Longitudinal study using eight waves (2006–2020) of the Korean Longitudinal Study of Aging.

Setting Nationally representative sample of the Korean population aged 45 years and older.

Participants 2170 workers aged 45 and older at baseline.

Primary outcome measures Cognitive function was evaluated using the Korean version of the Mini-Mental State Examination and cognitive impairment was defined as a score below 24.

Results High physical strength demands were inversely associated with cognitive impairment (OR 0.31, 95% CI 0.14 to 0.68 for 'always' vs 'never' category). Conversely, frequent heavy lifting (OR 2.67, 95% CI 1.36 to 5.26) and bending, kneeling or squatting (OR 1.69, 95% CI 0.82 to 3.47) tasks were associated with increased impairment risk. Dose–response relationships were observed between all physical job demands and cognitive impairment, persisting among those with lower education but not among those with higher education.

Conclusions Different types of physical job demands have varying relationships with cognitive impairment in middle-aged and older workers. Tasks requiring high physical strength may protect against cognitive impairment while tasks involving heavy lifting and bending, kneeling or squatting may increase the risk. These findings highlight the need for tailored interventions that consider the type of physical job demands and workers' educational levels to mitigate cognitive impairment risks. Further research is needed to explore the underlying mechanisms and validate these findings.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study used a nationally representative sample of middle-aged and older Korean workers, enhancing the generalisability of the findings.
- ⇒ Long-term periodically repeated evaluations over 14 years allowed for a comprehensive assessment of the relationship between physical job demands and cognitive impairment.
- ⇒ Physical job demands were assessed using simple questionnaires, which may be less valid and more prone to misclassification bias compared with device-based methods.
- ⇒ The study may be subject to potential bias due to loss to follow-up, although generalised linear mixed-effects models were used to mitigate this issue.
- ⇒ The 2-year interval between surveys introduces the possibility of carry-over effects from job changes, which could lead to misclassification bias.

INTRODUCTION

Cognitive function, which includes memory, attention and problem-solving, is vital for mental well-being, especially in middle-aged and older populations. As individuals age, maintaining and improving cognitive abilities becomes essential for independence and quality of life. These abilities are not fixed but can change due to various factors such as physical health,[1] mental stimulation[2] and social engagement, including work.[3] This flexibility suggests that cognitive decline is not an unavoidable consequence of ageing but can be reduced or even reversed through suitable interventions. In the context of the ageing population in Korea, it is imperative to explore factors that may contribute to cognitive impairment, including dementia. Notably, the increase in the prevalence of dementia in Korea from 2021 to 2050 is expected to be the largest among the Organisation for Economic Co-operation and Development countries.[4] Previous studies have proposed that several risk factors in middle and old age, including cardiovascular disease, are linked with an increased risk of cognitive impairment later in life.[5 6]

Studies on occupational risk factors for cognitive impairment have primarily focused on job complexities based on the International Standard Classification of Occupations and exposure to hazardous substances rather than physical job demands.[7 8] This may be attributed to the widespread and well-established perception that physical activity benefits health. However, there is growing evidence that physical job demands, unlike leisure-time physical activities (LTPAs), may paradoxically increase the risk of cognitive impairment.[9–11] Previous studies elucidating the relationship between physical job demands and cognitive impairment present several limitations, including the lack of a nationally representative sample,[11] limited categories of occupations,[9 10 12] lack of periodic repeated evaluations[9 10 12] and inadequate adjustment for potential confounders.[11] Many of these studies have relied on self-reported data and single-time point assessments, which can introduce recall bias and limit the ability to capture the dynamic nature of physical job demands over time.[13] Specifically, studies have yet to attempt to explore the relationship between the subelements of physical job demands (physical strength (PS), lifting heavy objects (LH) and bending, kneeling or squatting (BK)) and cognitive impairment. Exploring the risk of cognitive impairment by subelements of physical job demands and evaluating the presence of effect modification may help generate hypotheses about potential risk factors and mechanisms while contributing to policymaking and implementing tailored interventions to reduce the socioeconomic burden of cognitive impairment.

In this study, we aimed to address a substantial gap in the literature by examining the association between physical job demands and the risk of cognitive impairment in middle-aged and older populations using a national panel survey database in Korea. We hypothesised that subelements of physical job demands would affect cognitive impairment differently, particularly with regard to PS and LH, which we expected to have contrasting associations.

METHODS

Data source

We used the Korean Longitudinal Study of Aging (KLoSA) survey database.[14] A detailed description of the KLoSA survey database has been published elsewhere.[15 16] Briefly, the KLoSA survey database is a nationwide database collected biennially since 2006 that covers the middle-aged and older Korean population; it includes information regarding demographics, family, health, employment, income, assets, subjective expectations and satisfaction. KLoSA benchmarked prior experiences of the Health and Retirement Study in the USA, the English Longitudinal Study of Ageing in the UK and the Survey of Health, Ageing and Retirement in Europe, which were panel surveys for older adults. KLoSA covered all the key topics of these surveys during the development stage. The KLoSA survey used a stratified two-stage cluster sampling technique to obtain a representative sample of the Korean population aged 45 years and older.

Study design and participants

We conducted a longitudinal study using data from eight waves (2006–2020) of the KLoSA database. All participants surveyed at baseline (ie, the first wave) in 2006 were included (10 254 participants) in the study. Eligibility criteria were defined as being workers aged 45 years and older (2170 participants). Considering that the KLoSA database is complex survey data, we implemented subpopulation analysis for subjects that met the eligibility criteria without deleting any observations. During the study period, some participants changed jobs or retired. Therefore, to establish a temporal relationship and minimise reverse causation between physical job demands and cognitive impairment, only observations of those who had been at least 3 months in the job identified at each survey wave were included in the analysis.

Measurements

Physical job demands

In each of the eight survey waves, the participants were asked if they were currently working for income. Participants who answered 'yes' were asked three questions about their physical job demands: (1) How often do you need a lot of physical strength to perform tasks in your job? (2) How often do you need to lift heavy objects to perform tasks in your job? (3) How often do you need to bend, kneel or squat to perform tasks in your job? Response options were rated on a four-point scale (never, sometimes, often, always).

Cognitive function

The Korean version of the Mini-Mental State Examination (K-MMSE) was used to measure cognitive function.[17] The K-MMSE comprises 30 points calculated using 19 items in seven domains: time orientation, place orientation, memory registration, attention, memory recall, language and visual construction. The MMSE cut-off score depends on the purpose of the study; however, in general, a score of less than 24 is considered an acceptable cut-off indicative of the presence of cognitive impairment.[18] Hence, we adopted the above criteria and defined cognitive impairment as a score of fewer than 24 points.

Covariates

For potential confounders, we selected 17 characteristics from three domains: sociodemographic, health related and occupational. All covariates were chosen using the modified disjunctive cause criterion proposed by VanderWeele.[19] Sociodemographic characteristics included age, sex, marital status, educational attainment, household income (adjusted household size by square root equivalence scale) and residential area. Health-related characteristics included obesity (based on the Asia-Pacific guidelines of the WHO),[20] smoking, risky drinking (based on the criteria of the Korea National Health and Nutrition Examination Survey),[21] physical activity (based on the WHO guidelines),[22] hypertension, diabetes and depressive symptoms (based on the 10-item Centre for

Epidemiologic Studies Depression Scale).[23] Occupational characteristics included weekly work hours, employment status and occupational groups based on the Korean Standard Classification of Occupations (KSCO). The occupational groups classified according to the KSCO were (1) managers; (2) professionals and related workers; (3) clerks; (4) service workers; (5) sales workers; (6) skilled agricultural, forestry and fishery workers; (7) craft and related trades workers; (8) equipment, machine operating and assembling workers; (9) elementary workers and (10) unspecified.

Statistical analysis

Our primary interest was an association between physical job demands and the weighted prevalence of cognitive impairment. Graphs were constructed to visualise trends in the prevalence of cognitive impairment according to physical job demands during 2006–2020. We fitted generalised linear mixed-effects models (GLMM) with random intercepts and a logit link function. The regression equation was

$$\text{logit}\left(\Pr\left(\textit{impairment}_{it}=1\right)\right)=\beta_0+\alpha_i + \beta_1\left(\textit{physical job demand}_{it}\right)+\sum\beta_{2j}X_{itj}$$

where $\textit{impairment}_{it}$ is the cognitive impairment status for subject i at wave t, β_0 is the global intercept, α_i is the random intercept for subject i, $\textit{physical job demand}_{it}$ is the physical job demand status in the job identified at wave t for subject i and X_{itj} is the covariate j for subject i at wave t. Since our research question focused on workers, which constituted a subpopulation of the complex survey data, we implemented subpopulation analysis instead of excluding non-workers from the original dataset to compute correct standard errors. In addition, we assumed that the data were missing at random, under which GLMM can accommodate missingness due to loss to follow-up and produce unbiased estimates.

We estimated ORs and 95% CIs of physical job demands for cognitive impairment and repeated the analyses stratified by sex and educational attainment (middle school or below and high school or above) to assess the effect modification of these variables on the effect estimates. In addition, we separately fitted models with an interaction term between each physical job demand and potential effect modifier to identify populations with a higher or lower risk of cognitive impairment associated with physical job demands.

To address methodological concerns regarding the temporal relationship between physical job demands and cognitive impairment, we conducted a sensitivity analysis. We fitted a GLMM incorporating time-lagged variables and changes:

$$\text{logit}\left(\Pr\left(\textit{impairment}_{it+1}=1\right)\right)= \beta_0+\alpha_i+\beta_1\left(\textit{physical job demand}_{it}\right) + \beta_2\left(\textit{physical job demand change}_{(it+1)-(it)}\right)+\sum\beta_{3j}X_{itj}$$

Here, the dependent variable was the cognitive impairment status at time t+1 while the independent variables included the physical job demand at time t and the change in physical job demand from t to t+1. The physical job demand change was treated as a continuous variable, assuming equal intervals between categories.

Statistical significance was set at p≤0.05. Statistical analysis and graph construction were performed using Stata V.17.0 (StataCorp).

Patient and public involvement

Patients and the public were not involved in the design, conduct, reporting or dissemination plans of our research.

RESULTS

General characteristics of study participants

Table 1 (see the detailed version in online supplemental table 1) presents the descriptive characteristics of study participants at baseline in 2006. The participants' age ranged from 45 to 83 years. The most significant difference in baseline characteristics by physical job demands was found in the context of educational attainment. For simplicity, each physical job demand was dichotomised as low (never and sometimes) and high (often and always). Among participants in high PS demanding roles, 50.7% had an educational attainment of middle school or below, higher than the 23.8% in low PS demanding roles on the job. Similarly, among participants in high LH demanding roles, 53.1% had an educational attainment of middle school or below, higher than the 28.6% in low LH demanding roles on the job. Among participants in high BK demanding roles, 52.1% had an educational attainment of middle school or below, higher than the 25.4% in low BK demanding roles on the job.

Trends in the prevalence of cognitive impairment by physical job demands

Figure 1 and online supplemental table 2 present the prevalence of cognitive impairment according to physical job demands during the study period. Between 2006 and 2020, the prevalence of cognitive impairment among participants increased from 6.9% to 12.2%. Except for PS, a tendency was observed for the prevalence of cognitive impairment to increase with the increase in physical job demands in each wave. More detailed information regarding the distribution of workers across the levels of each physical job demand by the wave is presented in online supplemental table 3.

Longitudinal associations between physical job demands and cognitive impairment

Table 2 shows the results of GLMM with a logit link function examining the relationship between physical job demands and cognitive impairment. When all covariates and other physical job demands were adjusted, the 'always' category of LH and BK was associated with increased odds of cognitive impairment compared with

Table 1 Weighted characteristics of study participants by physical job demands* at baseline (wave 1) (condensed version)

	Total (n=2170)		Low PS (n=696)		High PS (n=1474)		Low LH (n=964)		High LH (n=1206)		Low BK (n=786)		High BK (n=1384)	
	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)
Age	53.2 (6.6)		52.6 (5.8)		53.5 (6.9)		52.6 (5.9)		53.7 (7.1)		52.4 (5.7)		53.7 (7.1)	
Sex (male)		1349 (66.5)		497 (74.1)		852 (62.5)		638 (69.6)		711 (63.7)		557 (74.0)		792 (61.5)
Educational attainment														
Elementary school or below		671 (22.6)		95 (9.6)		576 (29.5)		171 (12.7)		500 (31.6)		118 (10.9)		553 (30.4)
Middle school		434 (18.8)		121 (14.2)		313 (21.2)		178 (15.9)		256 (21.5)		130 (14.5)		304 (21.7)
High school		781 (40.8)		285 (41.1)		496 (40.6)		388 (41.3)		393 (40.3)		329 (42.4)		452 (39.7)
College or above		284 (17.8)		195 (35.1)		89 (8.7)		227 (30.1)		57 (6.6)		209 (32.2)		75 (8.2)
Smoking status														
Non-smoker		1331 (57.9)		414 (59.0)		917 (57.3)		602 (60.8)		729 (55.3)		472 (58.2)		859 (57.7)
Ex-smoker		256 (12.0)		101 (13.8)		155 (11.1)		119 (11.5)		137 (12.5)		102 (12.5)		154 (11.7)
Current smoker		583 (30.1)		181 (27.2)		402 (31.6)		243 (27.7)		340 (32.2)		212 (29.3)		371 (30.6)
Risky drinker† (no)		1888 (86.1)		598 (85.1)		1290 (86.6)		847 (87.1)		1041 (85.1)		685 (86.4)		1203 (85.8)
Physical activity‡ (sufficient)		781 (38.7)		367 (53.8)		414 (30.7)		471 (49.9)		310 (28.4)		415 (52.5)		366 (29.5)
Hypertension§ (no)		1778 (83.2)		560 (81.8)		1218 (84.0)		787 (83.1)		991 (83.3)		641 (83.1)		1137 (83.3)
Diabetes§ (no)		1995 (93.0)		629 (90.9)		1366 (94.0)		871 (91.6)		1124 (94.2)		716 (92.5)		1279 (93.3)
Depressive symptoms¶ (no)		2085 (96.8)		683 (98.3)		1402 (96.0)		937 (97.6)		1148 (96.1)		769 (97.8)		1316 (96.2)
Employment status														
Permanent worker		675 (35.6)		318 (51.7)		357 (27.1)		444 (51.7)		231 (21.0)		381 (53.3)		294 (23.8)
Temporary worker		127 (5.9)		35 (4.3)		92 (6.8)		56 (5.1)		71 (6.7)		38 (4.4)		89 (7.0)

Continued

Table 1 Continued

	Total (n=2170)		Low PS (n=696)		High PS (n=1474)		Low LH (n=964)		High LH (n=1206)		Low BK (n=786)		High BK (n=1384)	
	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)	Mean (SD)	n (%)
Day labourer		179 (8.4)		19 (2.1)		160 (11.6)		45 (3.7)		134 (12.6)		25 (2.6)		154 (12.2)
Self-employed worker		979 (42.9)		281 (36.9)		698 (46.1)		369 (35.5)		610 (49.6)		309 (36.5)		670 (47.1)
Unpaid family worker		210 (7.2)		43 (5.0)		167 (8.4)		50 (4.0)		160 (10.1)		33 (3.2)		177 (9.9)

All values, except the number of participants by category, were weighted estimates considering a complex sampling design.
*For simplicity, each physical job demand was dichotomised as low (never and sometimes) and high (often and always).
†High-risk drinkers were defined as individuals who consumed alcohol twice or more per week, based on the Korea National Health and Nutrition Examination Survey criteria.
‡Insufficient physical activity was defined as less than 150 min per week based on the WHO guidelines.
§Hypertension or diabetes cases were defined as those diagnosed with hypertension or diabetes by a physician.
¶Depressive symptoms were defined as a score of four or above on the 10-item Centre for Epidemiologic Studies Depression Scale.
BK, bending, kneeling or squatting; LH, lifting heavy objects; PS, physical strength.

the ‘never’ category, whereas the opposite was observed for PS. The ‘always’ category in PS, LH and BK, compared with the ‘never’ category, was associated with 0.31 (95% CI 0.14 to 0.68), 2.67 (95% CI 1.36 to 5.26) and 1.69-fold (95% CI 0.82 to 3.47) odds of cognitive impairment, respectively. In addition, dose–response relationships were observed between all physical job demands and the prevalence of cognitive impairment. However, when stratified by educational attainment, it was observed that the dose–response relationship was maintained among low-educated people while it disappeared among high-educated people. Figure 2 shows the combined effect of physical job demands and educational attainment on cognitive impairment, using highly educated people who fall into the ‘never’ category of physical job demands as the reference group for all comparisons.

Online supplemental tables 4–6 present the results of models fitted with an interaction term between each physical job demand and potential effect modifiers. Effect modification by potential effect modifiers (sex, educational attainment, household income, body mass index, smoking, physical activity, hypertension, diabetes, depressive symptoms and employment status) was not consistently detected across the physical job demands.

Sensitivity analysis

The results of the sensitivity analysis are presented in online supplemental table 7. The findings were consistent with our original results, demonstrating opposite directions of associations for PS and LH with cognitive impairment. The associations of changes in PS and LH from t to t+1 with cognitive impairment were in the same direction as their respective physical job demands at time t.

DISCUSSION

Using a national panel survey database in Korea, this study aimed to derive hypotheses regarding the physical activity paradox by examining the association between the subelements of physical job demands and the risk of cognitive impairment in the middle-aged and older population. We found that workers with tasks requiring high PS were less likely to suffer from cognitive impairment, whereas those with primary tasks of LH and BK were more likely to incur cognitive impairment. Notably, when stratified by educational attainment, it was observed that the dose–response relationship was maintained in those with low education, whereas it disappeared in those with high education.

The conventional wisdom that physical activity reduces the risk of various health outcomes has been firmly established by evidence that physical activity in all domains has similar beneficial effects. In particular, studies on occupational epidemiology before the 2010s reported that physically active jobs were associated with lower mortality risk.[24] However, recent studies have suggested differential health effects between occupational physical activities

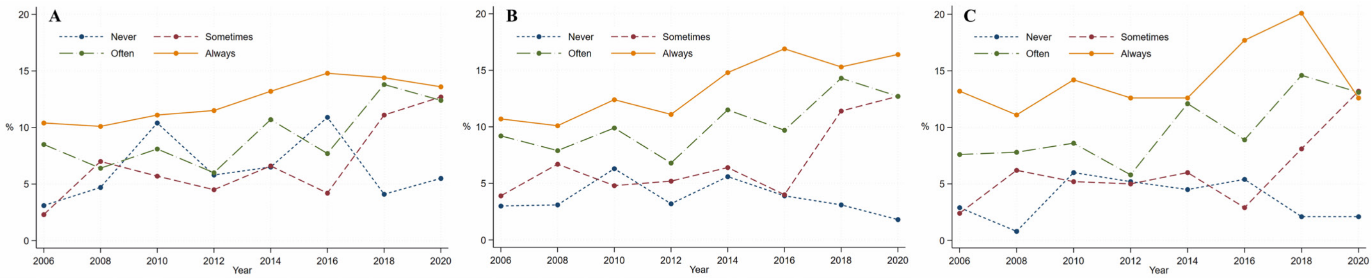

Figure 1 Weighted prevalence of cognitive impairment among study participants by physical job demands. (A) physical strength, (B) lifting heavy objects and (C) bending, kneeling or squatting

(for clarity, we refer to this as physical job demands) and LTPA, the so-called physical activity paradox.[25–27] One of the studies that received attention was a meta-analysis examining the association between physical job demands and mortality, which reported an 18% increase in risk for all-cause mortality among men with high physical job demands compared with those with low demands.[27] Several researchers have questioned the existence of this paradox by highlighting significant limitations of studies investigating the link between physical job demands and mortality. The accentuated limitations included crude categories for physical job demands, inadequate assessment using questionnaires with relatively low validity and potential for residual confounding.[28 29] In addition, studies published after the above-mentioned meta-analysis[27] showed inconsistent results, making it more challenging to distinguish whether these differential associations existed or were spurious results of methodological issues.[30–32] An umbrella review prepared for the 2020 WHO guidelines on physical activity and sedentary behaviour suggested that high physical job demands were conducive to most health outcomes, including coronary heart disease and several cancers, whereas unfavourably associated with all-cause mortality in men.[32]

Additionally, since studies on the health effects of physical job demands have been conducted primarily in the

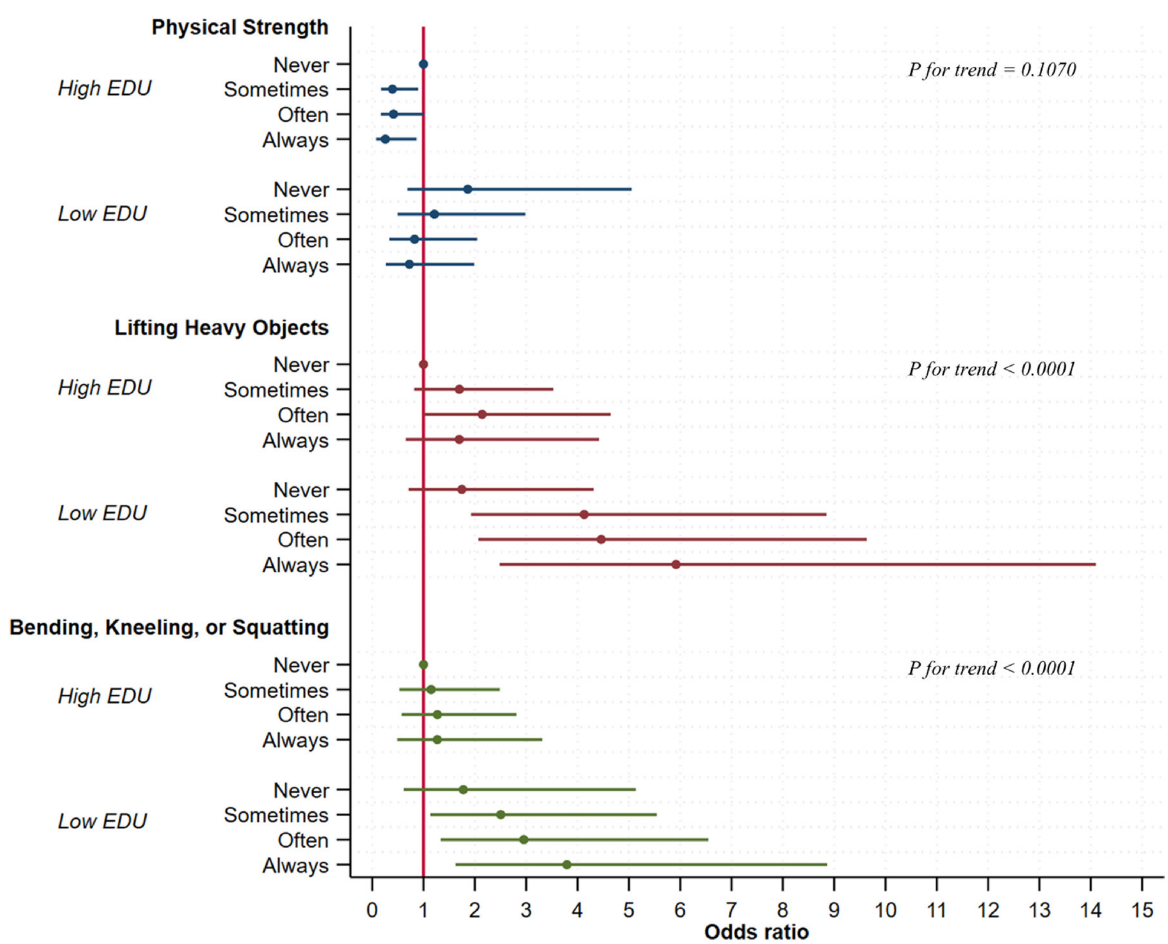

Figure 2 Combined effects of physical job demands and educational attainment on cognitive impairment. EDU, educational attainment.

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Table 2 Longitudinal associations between physical job demands and cognitive impairment

Physical job demands	Total						Male						Female					
	Total		Low EDU*		High EDU		Total		Low EDU		High EDU		Total		Low EDU		High EDU	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Physical strength																		
Never	Ref		Ref		Ref		Ref		Ref		Ref		Ref		Ref		Ref	
Sometimes	0.48	0.27 to 0.88	0.62	0.29 to 1.34	0.41	0.18 to 0.95	0.49	0.24 to 1.01	0.40	0.15 to 1.06	0.55	0.20 to 1.46	0.42	0.14 to 1.24	1.10	0.32 to 3.71	0.08	0.02 to 0.31
Often	0.40	0.21 to 0.75	0.41	0.19 to 0.87	0.47	0.18 to 1.18	0.48	0.22 to 1.03	0.36	0.14 to 0.97	0.62	0.21 to 1.80	0.26	0.09 to 0.78	0.56	0.17 to 1.85	0.10	0.02 to 0.50
Always	0.31	0.14 to 0.68	0.32	0.14 to 0.74	0.42	0.10 to 1.75	0.32	0.11 to 0.93	0.24	0.08 to 0.73	0.56	0.10 to 3.30	0.26	0.08 to 0.79	0.55	0.16 to 1.93	0.10	0.02 to 0.50
Lifting heavy objects																		
Never	Ref		Ref		Ref		Ref		Ref		Ref		Ref		Ref		Ref	
Sometimes	2.01	1.17 to 3.46	2.22	1.09 to 4.52	1.71	0.81 to 3.61	1.81	0.92 to 3.60	2.70	0.92 to 7.87	1.45	0.62 to 3.39	2.38	0.98 to 5.82	1.83	0.69 to 4.81	7.81	1.60 to 38.17
Often	2.29	1.30 to 4.06	2.49	1.20 to 5.17	1.91	0.83 to 4.41	1.85	0.87 to 3.91	2.12	0.68 to 6.61	1.64	0.63 to 4.29	3.15	1.29 to 7.73	2.68	1.02 to 7.06	8.34	1.60 to 43.45
Always	2.67	1.36 to 5.26	3.46	1.49 to 8.06	1.26	0.44 to 3.62	2.37	0.95 to 5.94	3.56	0.95 to 13.40	1.15	0.33 to 4.00	3.28	1.19 to 9.02	3.13	1.05 to 9.37	3.16	0.50 to 19.98
Bending, kneeling or squatting																		
Never	Ref		Ref		Ref		Ref		Ref		Ref		Ref		Ref		Ref	
Sometimes	1.25	0.68 to 2.32	1.15	0.48 to 2.73	1.38	0.61 to 3.12	1.30	0.63 to 2.70	1.82	0.53 to 6.25	1.12	0.47 to 2.67	1.16	0.37 to 3.60	0.53	0.16 to 1.77	2.57	0.41 to 16.09
Often	1.43	0.75 to 2.73	1.54	0.63 to 3.73	1.28	0.53 to 3.11	1.66	0.77 to 3.57	2.79	0.87 to 8.89	1.20	0.45 to 3.19	1.04	0.32 to 3.43	0.61	0.16 to 2.37	1.20	0.15 to 9.34
Always	1.69	0.82 to 3.47	1.84	0.70 to 4.80	1.49	0.48 to 4.65	2.09	0.86 to 5.08	3.67	0.99 to 13.64	1.34	0.37 to 4.86	1.06	0.30 to 3.70	0.64	0.16 to 2.59	1.53	0.12 to 19.99

Adjusted for sociodemographic, health-related, occupational characteristics and other physical job demands.
*Educational attainment was dichotomised as low EDU (middle school or below) and high EDU (high school or above).
EDU, educational attainment; Ref, reference.

context of cardiovascular disease and mortality outcomes, epidemiological evidence for cognitive impairment and dementia remains scarce. Previous studies on physical job demands and cognitive impairment revealed mixed results, and these studies shared the aforementioned limitations of studies examining the relationship between physical job demands and mortality.[9–12] A meta-analysis and systematic review exploring the association between physical job demands and cognitive impairment was inconclusive,[33 34] and the umbrella review mentioned above[32] excluded the evidence for neurological disorders. Given the need for a response to unprecedented rapid ageing at a national level and the fact that the relationship between physical job demands and cognitive impairment has not been fully explored, we searched for available secondary data that fulfilled the research agenda for the physical activity paradox proposed by Coenen *et al*[35] to the greatest extent. Furthermore, we noted the common conclusion of previous studies that future research should consider various aspects of physical job demands. Most studies assessing physical job demands through job exposure matrices[11] or questionnaires combined multiple items into a single measure and classified them into crude categories (active and sedentary or quantiles).[9 10 12] Dalene *et al* pointed out that since physical job demands comprise a mixture of beneficial and detrimental exposures, treating physical job demands as an all-inclusive term might have a neutralising effect.[36] Therefore, we attempted to examine the relationship between cognitive impairment and subelements of physical job demands, including PS (as a surrogate measure of energy expenditure) and biomechanical components (LH and BK).

Our results, which suggested that associations with cognitive impairment for subelements of physical job demands were in different directions, are consistent with the plausible physiological explanations from previous studies. Existing evidence supports the concept that age-related impairment of autoregulatory adaptation to transient increase or decrease in blood pressure contributes to increased susceptibility of older adults to microvascular brain damage and cognitive decline. Valsalva manoeuvres, unavoidable when LH, cause a significant transient increase in arterial pressure for a short period, posing a challenge to the autoregulatory mechanisms of cerebral circulation.[37] Postural changes induce short-term blood pressure instability, which may play a role in accelerating cognitive ageing,[38] although our results for BK were not statistically significant. In contrast, performing tasks requiring PS may have potential protective mechanisms against brain ageing, similar to LTPAs that promote amyloid beta peptides clearance, modulate oxidative stress and inflammation, and enhance neurogenesis and neuroplasticity.[39] Our results also provided insight into why the results of previous studies were inconsistent and the so-called physical activity paradox was observed. The subelements of physical job demands that are more dominant may determine if the physical job demands are beneficial or detrimental to specific health outcomes. We posited that an integrated approach is needed to understand the physical activity paradox. First, subelements of physical job demands influencing specific health outcomes should be identified using a reductionist approach, and then indicators should be developed considering multiple subelements via a holistic approach.

Another notable result, that the dose–response relationship was maintained among low-educated subjects but dissipated among their highly educated counterparts, is also consistent with two inter-related hypotheses in previous studies. First, the concept of cognitive reserve suggests that individuals with higher levels of education may have a more resilient neural network and better cognitive processing, which could make them less influenced by the effects of physical job demands on the brain.[40] Second, highly educated individuals are likely to engage in tasks necessitating substantial cognitive involvement in their occupations. The routine utilisation of cognitive skills in problem-solving and decision-making may foster cognitive resilience, enabling them to withstand the effects of physical job demands on the brain.[41] This suggests an important implication: individuals with lower levels of education are not only more likely to face physical job demands but are also more vulnerable to the effects of such demands. Therefore, this group is the one that can benefit the most from tailored interventions and should be given the highest priority in public health policies. To mitigate the risk of cognitive impairment among middle-aged and older workers, particularly those with lower educational attainment and high LH and BK demanding roles, we propose two main types of personalised interventions. First, modifications in the work environment or job tasks can be implemented to alleviate LH and BK burdens, such as job redesign, ergonomic solutions and more rest periods during work hours. Second, programmes designed to enhance cognitive abilities and resilience can be introduced, which can help workers improve their cognitive performance and potentially counteract the adverse effects of LH and BK burdens on the brain.

Strengths of the present study include national-level representative samples of the middle-aged and older Korean population, long-term periodically repeated evaluations and encompassment of various occupational groups. Additionally, we extensively addressed the residual confounding and effect modification issues. Furthermore, we shed light on the relationship between the subelements of physical job demands and cognitive impairment to advance knowledge about the physical activity paradox.

Nevertheless, this study had several limitations. First, the risk of reverse causality cannot be entirely ruled out. It is possible that individuals experiencing early stages of cognitive decline might be more likely to change jobs or stop working altogether, potentially influencing our observed associations. Second, there was a large proportion of participants who lost to follow-up before the last wave. Participants who developed cognitive impairment may have been more likely to drop out of the study. While we implemented GLMM to obtain unbiased estimates under the assumption that data is missing at random, the possibility of data missing not at random cannot be completely discounted, which could lead to biased estimates. Third, we assessed physical job demands using simple questionnaires, which are less valid and prone to differential misclassification bias compared with device-based methods. We recognised this as one of the limitations of the existing literature and searched for available secondary data that applied device-based methods, but unfortunately, none existed. Fourth, the possibility of carry-over effects warrants consideration. The 2-year interval between surveys introduces the potential for participants to have changed jobs multiple times. Our data only reflect the physical demands of the job held at the time of each survey, which could lead to a misclassification bias due to carry-over effects from previous jobs. To address this, our analysis only includes observations from participants who had been in jobs identified at the time of each survey wave for at least 3 months. However, this approach only partially eliminates the potential for bias. Fifth, our study did not account for early-life cognitive ability, which recent research suggests may be a stronger predictor of cognitive abilities later in life than education or occupational characteristics.[42 43] Individuals with higher cognitive abilities early in life are more likely to choose cognitively challenging occupations and are less likely to experience cognitive decline. This unmeasured confounding factor could partially explain the associations observed in our study. Future research should consider incorporating measures of early-life cognitive ability to better understand its role in the relationship between physical job demands and cognitive impairment.

Conclusion

Our research suggests that various physical job demands may have differing relationships with cognitive impairment in middle-aged and older workers. Tasks necessitating high PS were linked to a decreased likelihood of cognitive impairment while tasks involving heavy lifting and BK were associated with an increased risk. These relationships were more pronounced in workers with lower educational attainment. These insights add to our understanding of the 'physical activity paradox' and suggest that future research and interventions should consider the specific aspects of physical job demands. While our findings provide important insights, the observational nature of our study and potential for biases such as reverse causality and loss to follow-up limit our ability to draw definitive causal conclusions. Further research using diverse methodological approaches is required to validate these findings, investigate potential underlying mechanisms and strengthen causal inferences regarding the relationship between physical job demands and cognitive impairment.

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ORCID iDs
Jea Chul Ha http://orcid.org/0000-0002-1868-619X
Jin-Ha Yoon http://orcid.org/0000-0003-4198-2955

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