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Original Article

Dose- and pattern- physical activity is associated with lower risk of dementia

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ABSTRACT

Background: The amount and pattern of physical activity that benefits cognitive health remain unclear.
Methods: Participants from the UK Biobank cohort who had a full week of accelerometer-based moderate-to-vigorous physical activity (MVPA) and light physical activity (LPA) data were included in the analysis. The data for dementia diagnosis were collected from 2006 to 2024. Associations between the incidence of all-cause dementia, Alzheimer's disease (AD), vascular dementia (VaD), and PA amounts and patterns were assessed using Cox proportional hazards regression models. The analysis included 1) comparing MVPA gradients with reference group performing less than 150 min/week; 2) classifying MVPA patterns as effective intensive (≥300 min/week with ≥50 % of MVPA in 1–2 days), effective regular (≥300 min/week not up to effective intensive), and ineffective (<300 min/week); 3) performing stratified analyses by age, sex, and *APOE* ε4 carrier status; and 4) evaluating the association between LPA and dementia risk among participants classified as ineffective MVPA levels.
Results: 91,512 individuals (mean [SD] age, 56.03[7.8] years; 55.9 % female) were included. Compared with participants performing <150 min of MVPA per week, those accumulating 150–299 min/week, whether through concentrated (1–2 days) or regular pattern, did not show significantly lower dementia incidence. However, accumulating >300 min/week of MVPA was associated with a reduced risk. When stratified at 300 min/week of MVPA, hazard ratios for dementia were 0.73 (95 % CI: 0.60–0.89) for the weekend pattern and 0.79 (95 % CI: 0.64–0.98) for the regular pattern. For ineffective MVPA, engaging in >840 min/week of LPA was associated with lower dementia incidence.
Conclusions: Accumulating >300 min/week of MVPA, whether concentrated within 1–2 days or distributed evenly across the week, was associated with a decreased risk of dementia. Additionally, higher levels of LPA partially compensated for low MVPA in lowering dementia risk.

1. Introduction

Physical activity (PA) is widely recognized for its health benefits and role in reducing dementia risk [1]. According to the World Health Organization's (WHO) 2020 Guidelines on Physical Activity and Sedentary Behavior, adults and older adults should aim to participate in a minimum of 150–300 min of moderate-intensity PA, 75–150 min of vigorous-intensity PA, or an equivalent combination of moderate-to-vigorous physical activity (MVPA) each week for substantial health benefits [2]. However, the current evidence falls short in elucidating the precise dose–response relationship between PA and the incidence of dementia, necessitating further research [2]. Moreover, light-intensity physical activity (LPA) has shown considerable potential for improving health outcomes in a dose-dependent manner [3,4]. Since achieving the MVPA intensity may be challenging for some older adults, LPA may be a suitable alternative for reducing dementia incidence. However, no relevant guidelines were recommended.

The UK National Health Service advises that MVPA be spread "evenly over 4–5 days/week, or daily" [5]. However, it remains unclear whether spreading PA over more days or concentrating most of PA into 1–2

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Categories	Total n	Event	Hazard ratio (95% CI)	P value
All−cause dementia				
<150 min/week	29155	308	1(ref)	
150−299 min/week	25697	228	0.94(0.79−1.12)	0.463
300−600 min/week	26678	180	0.78(0.64−0.94)	0.010
>600 min/week	9982	52	0.61(0.45−0.83)	0.001
Alzheimer's disease				
<150 min/week	29155	130	1(ref)	
150−299 min/week	25697	95	0.93(0.71−1.21)	0.571
300−600 min/week	26678	71	0.75(0.55−1.01)	0.058
>600 min/week	9982	24	0.71(0.45−1.11)	0.129
Vascular dementia				
<150 min/week	29155	62	1(ref)	
150−299 min/week	25697	48	1.03(0.70−1.51)	0.894
300−600 min/week	26678	32	0.73(0.46−1.14)	0.162
>600 min/week	9982	7	0.42(0.19−0.94)	0.036

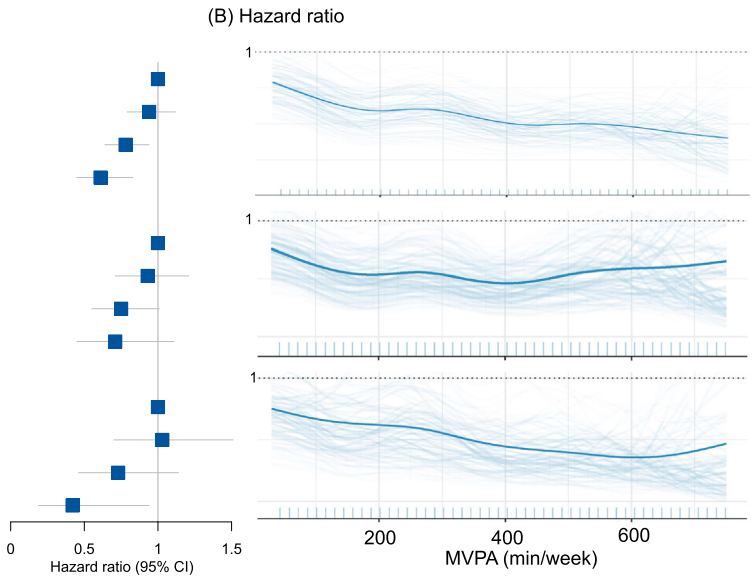

Fig. 1. Dose-response association between MVPA and incident dementia.
A, Depicted are plots of multivariable-adjusted associations between the levels of MVPA and incident all-cause dementia, Alzheimer's disease and Vascular dementia. Three groups are compared with the lowest level of MVPA. B, dose-response associations between MVPA and dementia (the y-axis represented Hazard ratio). Bars depict 95 % confidence intervals. MVPA: moderate to vigorous physical activity.

days (intensive pattern) offers the same benefits or differs for dementia incidence. Recently, it was reported that the "weekend warrior" pattern may be a viable alternative for promoting brain health [6]. Additionally, a longitudinal analysis suggests that individuals who exercise or engage in sports once or twice per week have a lower risk of mild dementia than individuals who reported no sport or exercise [7]. However, these studies did not comprehensively evaluate the optimal amount of PA associated with reduced dementia risk. Moreover, there is a scarcity of research that simultaneously examines the impact of the optimal amount of PA and its pattern on the incidence of dementia.

Based on PA data from wrist-based accelerometers in a UK Biobank prospective cohort, we assessed the optimal MVPA amount and patterns associated with lower dementia risk. First, we analyzed the dose–response relationship between MVPA and dementia incidence to identify the effective MVPA threshold associated with reduced risk. Second, we compared the effects of the effective intensive pattern and effective regular pattern on dementia incidence in multifactor-adjusted models. Third, we examined the dose-dependent effects of LPA on dementia incidence in individuals who did not achieve effective MVPA.

2. Methods

2.1. Study design and population

This prospective cohort study is based on a UK Biobank cohort, which enrolled over 500,000 individuals aged 37–73 years at baseline from the general population (5.5 % response rate) [8]. Between 2006 and 2010, participants visited one of 22 assessment research centers across Scotland, England, and Wales [9,10]. Follow-up data were collected up to April 2024.

We included 502,241 individuals at baseline. Exclusions were made for individuals who (1) were under 40 years old; (2) self-reported cognitive impairment, AD, or dementia at baseline; (3) were diagnosed with dementia; or (4) had missing data on PA and covariates. Ultimately, 91,512 participants were included in the final analysis. A flowchart of the subject selection process is shown in Figure S1. All participants provided written informed consent. The UK Biobank study was approved by the North West Multi-Center Research Ethics Committee.

2.2. Physical activity assessment

An Axivity AX3 wrist-worn triaxial accelerometer was used to collect objective PA data from 100,083 UK Biobank participants between 2013 and 201,5[11]. To ensure accurate classification of activity patterns, participants with less than a week of acceleration data were excluded (allowing for imputed values; see Fig. 1). All variables used are available to registered researchers through the UK Biobank Data Showcase (moderate-vigorous day average: Field 40,045; daily wear time: Fields 90,053–90,059; completeness of acceleration epochs: Field 90,004).

Furthermore, to determine the effective MVPA, individuals were categorized into four groups based on their MVPA levels: (i) <150 min/week; (ii) 150–299 min/week; (iii) 300–599 min/week; and (iv) ≥600 min/week[2]. Once effective MVPA was established, individuals were further classified into three physical activity patterns, namely effective intensive (at or above the MVPA threshold with ≥50 % of total MVPA over 1–2 days), effective regular (at or above the MVPA threshold but not meeting the effective intensive criteria), and ineffective (below the MVPA threshold) [12].

For the ineffective group, LPA was further categorized into eight levels to assess the dose–response association with dementia incidence: (i) <420 min/week, (ii) 420–839 min/week, (iii) 840–1259 min/week, (iv) 1260–1679 min/week, (v) 1 680–2099 min/week, (vi) 2100–2519 min/week, (vii) 2520–2939 min/week, and (viii) ≥2940 min/week.

2.3. Dementia assessment

The diagnosis data were linked to UK electronic health records, with dementia cases reported by professional clinicians in hospitals, family doctors in the primary care system, or staff in the death registration system. Dementia cases were identified and classified using the International Classification of Diseases (ICD)-9 and ICD-10 codes [13]. Participants with a prior diagnosis of dementia or any other neurological condition were excluded from the analysis. The primary outcomes included incident cases of all-cause dementia, AD, and vascular dementia (VaD). These were identified from the first occurrence reports (Fields 131,036–37, 130,836–43), algorithm definitions (Fields 42,018–25), death registrations (Fields 40,001–02), and hospital inpatient data summaries

(Fields 41,270–80). The outcome date for dementia diagnosis was based on the earliest recorded data from any of the above sources.

2.4. Covariates

Covariates included sociodemographic factors (age, sex, education, ethnicity, and Townsend deprivation index), lifestyle factors (smoking status, alcohol status, and diet quality), diseases (diabetes, hypertension, heart attack, and stroke), and a genetic factor (*APOE* ε4 status). Age and education were considered continuous variables. Sex was classified as female or male. Ethnicity was categorized as White, Black, Asian, or Other. Smoking status was classified as never, former, or current smoker. Alcohol consumption was categorized as never, previously, or currently consumed. Deprivation (area-based socioeconomic status) was derived from the residence postcode, using the Townsend score, a continuous scale [14]. Diet quality was categorized as unhealthy, healthy, and intermediate [15]. Diseases, including diabetes, hypertension, heart attack, and stroke, were categorized as "yes" or "no." The above covariates were collected during the baseline period within the UK Biobank database. *APOE* genotypes were derived from rs7412 and rs429358. Continuous body mass index, calculated as weight in kilograms divided by height in meters squared, was included in the model as a covariate.

2.5. Statistical analyses

Descriptive statistics for MVPA categories are presented as means with standard deviation (SD) for quantitative variables, medians with interquartile range (IQR) for skewed quantitative variables, and frequencies with percentages for categorical variables. Cox proportional hazard models were used to compare 1) the dose–response relationship of MVPA using four MVPA groups; 2) ineffective, effective regular, and effective intensive groups; 3) ineffective and effective groups; and 4) effective regular and effective intensive groups. All the analyses above were adjusted for all covariates and the LPA amount. The dose–response association between LPA and dementia incidence in the ineffective MVPA group was investigated using Cox proportional hazards models; individuals with <420 min/week of LPA served as the reference group. These analyses were adjusted for the same covariates and total MVPA. The results were reported as hazard ratios (HRs) with 95 % confidence intervals (CIs). Furthermore, we conducted subgroup analyses for dementia subtypes, including AD and VaD.

Additionally, a sensitivity analysis was performed, excluding individuals who were diagnosed with dementia within 2 years of accelerometer measurement to reduce potential confound from reverse causality. Another sensitivity analysis was performed to eliminate the influence of the baseline period. The baseline was re-defined as the period during which MVPA data were collected (2013–2015). We conducted subgroup analyses based on baseline categories of age (40–50, 51–60, and 61–70 years) and sex (female vs. male). *APOE* is an internationally recognized susceptibility gene for dementia. Of the 91,512 individuals included, only 76,406 had *APOE* gene data. Therefore, we did not include *APOE* as a covariate in the primary analysis. We also conducted a stratified analysis of *APOE* ε*4* carrier status (Yes or No). The guideline-based threshold ($\geq$ 150 min/week) was used as an alternative to assess the association between MVPA and dementia incidence. Analyses were conducted using R Version 4.0 [16] and SPSS 22.0 statistical software. A p-value < 0.05 was considered statistically significant.

3. Results

3.1. Population characteristics

Our study included 91,512 participants aged 40–70 years who had their PA measured using wrist-based accelerometers in the UK Biobank (Table 1). The average age was 56.03 (SD = 7.8) years; 51,159 (55.9 %) were female, and 88,797 (97.0 %) were non-Hispanic White. The median follow-up time was 15.25 years [IQR, 14.50–15.92 years].

3.2. Dose–response relationship between MVPA and incident dementia

In the multivariable-adjusted models, all-cause dementia risk decreased with increasing MVPA levels (Fig. 1). Compared with participants with <150 min/week MVPA, those with 150–299 min/week did not have a significantly lower all-cause dementia incidence (HRs: 0.94 [95 % CI: 0.79–1.12], p = 0.463), while those with more than 300 min/week of MVPA had a significantly reduced incidence (HRs: 0.78 [95 % CI: 0.64–0.94] for 300–600 min/week, HRs: 0.61 [95 % CI: 0.45–0.83] for >600 min/week). The 300 min/week of MVPA as the threshold was used to define the effective and ineffective groups. For AD and VaD, the dose–response association showed a similar trend with all-cause dementia (Fig. 1). In the sensitivity analysis, similar results were found with a 2-year blanking period (Table S1). Sex, age, and *APOE* ε4 status stratification analysis

In sex- stratified subgroup (Fig. 2A-C), more than 300 min/week of MVPA was significantly associated with lower dementia incidence in male [HRs: 0.77 (95 % CI: 0.60–0.98)], while it needs to be more than 600 min/week of MVPA to associated with lower incidence of all-cause dementia in female [HRs: 0.37 (95 % CI: 0.17–0.80)]. In most of the age-stratified subgroups, there was a declining trend in dementia incidence with the increasing time of MVPA per week (Fig. 2D-F). The MVPA dose-adjusted models in the 61–70 years old subgroup showed HRs for all-cause dementia were 0.77 (95 % CI: 0.62–0.95) for 300–599 min/week, and 0.55 (95 % CI: 0.39–0.78) for more than 600 min/week. In the *APOE* ε4 status-stratified subgroup (Fig. 2G-I), MVPA was only significantly associated with lower dementia incidence in *APOE* ε4 noncarriers but not carriers. In MVPA dose-adjusted models in *APOE* ε4 noncarriers, HRs for all-cause dementia were 0.78 (95 % CI: 0.60–1.03) for 150–299 min/week, 0.63 (95 % CI: 0.46–0.85) for 300–599 min/week, and 0.46 (95 % CI: 0.28–0.75) for >600 min/week by comparing with those for <150 min/week of MVPA.

3.3. Effective intensive pattern and effective regular pattern versus ineffective MVPA

Stratified at the optimal threshold of MVPA at 300 min/week, 19,770 (21.8 %), 16,890 (18.5 %), and 54,825 (59.9 %) participants were in the effective intensive, effective regular, and ineffective groups, respectively (Table 1). Dementia incidence rate, including all-cause dementia, AD, and VaD, was remarkably lower in participants with effective MVPA than with ineffective MVPA (Table S2). In the MVPA pattern-adjusted models (Fig. 3, Table S3), HRs for all-cause dementia were 0.73 (95 % CI: 0.60–0.89) for effective intensive and 0.79 (95 % CI: 0.64–0.98) for effective regular participants. For AD and VaD, the HRs were also analyzed in Table S2. All results remained similar after adding LPA to the models (Table S3). When the MVPA data collection period was set as the baseline, the median [IQR] follow-up time with this adjusted baseline was 8.58 [8.00, 9.08] years. Notably, the sensitivity analysis using the redefined baseline exhibited consistent trends and retained statistical significance for the results (Table S4).

Compared to participants with an effective regular pattern, those with the effective intensive pattern had HRs of 0.91 (95 % CI: 0.70–1.18) for all-cause dementia, 1.15 (95 % CI: 0.76–1.75) for AD, and 1.11 (95 % CI: 0.58–2.12) for VaD (Table S2). The cumulative crude HRs between activity patterns and all-cause dementia were determined by time of follow-up; compared with ineffective individuals, individuals with two effective patterns had similar lower curves (Fig. 3). The cumulative crude HR curves for AD and VaD are shown in Figure S2. The incidence of all-cause dementia, AD, and VaD was comparable between effective intensive and effective regular patterns (Table S2). When stratified by the guideline-based threshold of 150 min or more of MVPA

Table 1
Sample Characteristics of Participants in an Accelerometer-Derived Physical Activity Study.

Baseline characteristic	All	No. (%) Ineffective (n = 54,852)	Effective regular (n = 16,890)	Effective intensive (n = 19,770)
Sex				
Female	51,159(55.9)	34,406(62.7)	8057(47.7)	8696(44.0)
Male	40 353(44.1)	20 446(37.3)	8833(52.3)	1,1074(56.0)
Age, mean (SD), year	56.03(7.8)	56.51(7.8)	54.7(7.8)	55.84(7.7)
Race and ethnicity				
White	88,797(97.0)	53,071(96.8)	16,361(96.9)	19,365(98.0)
Black	724(0.8)	508(0.9)	125(0.7)	91(0.5)
Asian	1022(1.1)	696(1.3)	189(1.1)	137(0.7)
Other	969(1.1)	577(1.1)	215(1.3)	177(0.9)
Smoking status				
Never	52,655(57.5)	31,217(56.9)	9722(57.6)	11,716(59.3)
Previous	32,749(35.8)	19,592(35.7)	6157(36.5)	7000(35.4)
Current	6108(6.7)	4043(7.4)	1011(6.0)	1054(5.3)
Alcohol status				
Never	2530(2.8)	1762(3.2)	386(2.3)	382(1.9)
Previous	2407(2.6)	1562(2.8)	433(2.6)	412(2.1)
Current	86,575(94.6)	51,528(93.9)	16,071(95.2)	18,976(96.0)
Diet quality				
Health	16,244(17.8)	9313(17.0)	3388(20.1)	3543(17.9)
Intermediate	52,462(57.3)	31,423(57.3)	9627(57.0)	11,412(57.7)
Unhealth	22,806(24.9)	14,116(25.7)	3875(22.9)	4815(24.4)
Townsend Deprivation Index, mean (SD)	−1.75(2.8)	−1.8(2.8)	−1.3(3.0)	−2.0(2.7)
APOE				
ε4 carrier	19,628(25.7)	11,638(25.5)	3745(26.4)	4245(25.5)
ε4 noncarrier	56,778(74.3)	33,936(74.5)	10,417(73.6)	12,425(74.5)
Diabetes				
Yes	3032(3.3)	2228(4.1)	387(2.3)	417(2.1)
No	88,480(96.7)	52,624(95.9)	16,503(97.7)	19,353(97.9)
Heart attack				
Yes	1315(1.4)	929(1.7)	175(1.0)	211(1.1)
No	90,197(98.6)	53,923(98.3)	16,715(99.0)	19,559(98.9)
Hypertension				
Yes	20,384(22.3)	13,624(24.8)	3085(18.3)	3675(18.6)
No	71,128(77.7)	41,228(75.2)	13,805(81.7)	16,095(81.4)
Stroke				
Yes	840(0.9)	580(1.1)	107(0.6)	153(0.8)
No	90,672(99.1)	54,272(98.9)	16,783(99.4)	19,617(99.2)
Body mass index, mean (SD)	26.59(4.4)	27.2(4.7)	25.56(3.8)	25.78(3.7)
light-intensity physical activity, mean (SD), min/week	2131.02(704.3)	2132.88(721.9)	2136.90(708.5)	2120.84(704.3)
follow-up time, median [IQR], year	15.25 [14.50,15.92]	15.25 [14.50,15.92]	15.25 [14.50,15.92]	15.25 [14.50,15.92]

Note: SD, standard deviation; IQR, interquartile range.

per week, the effective intensive pattern was associated with lower all-cause dementia risk, whereas the effective regular pattern was not in the MVPA pattern-adjusted models (Fig. 3).

3.4. *Age, sex, and* APOE *ε4 status stratification analysis for MVPA pattern*

The age, sex, and *APOE ε*4 status stratification analysis of the MVPA pattern is shown in Supplementary Tables S5-S8. In the 61–70-year-old subgroup, significant associations were observed between effective intensive and a low all-cause dementia incidence (Table S5 and Table S6). In the MVPA pattern-adjusted models, significantly lower all-cause dementia was associated with effective intensive in both female and male subgroup [HRs: 0.63 (95 % CI: 0.44–0.91) and 0.78 (95 % CI: 0.61–0.99), respectively], but not effective regular pattern (Table S5 and Table S7). In *APOE ε*4 carriers, neither effective MVPA pattern was associated with dementia incidence (Table S5 and Table S8). However, in *APOE ε*4 noncarriers, HRs for all-cause dementia were 0.57 (95 % CI: 0.41–0.79) for effective intensive and 0.77 (95 % CI: 0.56–1.07) for effective regular participants.

3.5. *Dose–response association between light-intensity physical activity and dementia among individuals with ineffective MVPA*

For ineffective participants with <300 min/week of MVPA, we analyzed the dose–response associations between LPA and all-cause dementia, AD, and VaD after adjusting for the MVPA amount (Fig. 4). A significant trend emerged in the multivariable-adjusted models (Fig. 4), showing that higher LPA levels were associated with a lower dementia incidence. Specifically, compared to participants in the lowest category of LPA (<420 min/week), those who performed 420–839 min/week of LPA did not experience a significant reduction in all-cause dementia incidence. However, participants who performed >840 min/week had significantly lower all-cause dementia incidence. Similar trends were observed for AD, although the differences among the LPA categories were insignificant. For VaD, LPA levels >420 min/week were associated with lower event rates. The crude HRs for LPA categories, incident dementia, and follow-up time were simple and intuitive (Figure S3). In the stratification analysis based on sex, age, or *APOE* genotype, more than 840 min/week of LPA was associated with lower incidence of dementia

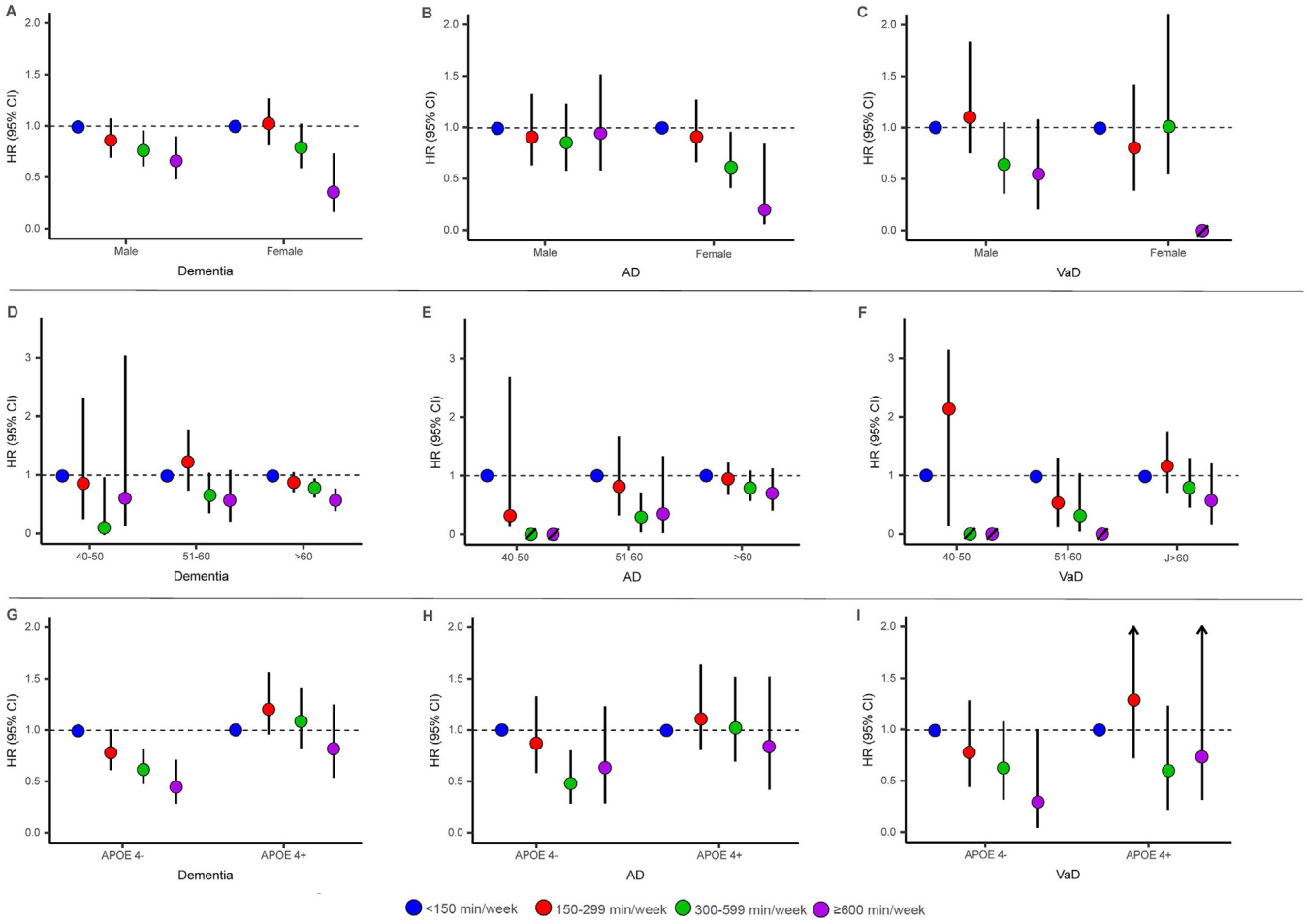

Fig. 2. Dose-response association between MVPA and incident dementia stratified by sex, age and *APOE* ε4 status.
Associations of MVPA gradients (<150 min/week,150–299 min/week, 300–599 min/week, and ≥600 min/week) with incidence of dementia stratified by sex (female and male) in A-C, age (40–50, 51–60, and > 60 years old) in d-F, *APOE* ε4 status (carriers and noncarriers) in G-I. All were adjusted for age (except for subgroup of age), sex (except for subgroup of sex), education, ethnicity, Townsend deprivation index, smoking status, alcohol status, diet quality, diabetes, hypertension, heart attack, stroke, body mass index, and total light-intensity physical activity. MVPA: moderate to vigorous physical activity. The slash represents that the incidence of dementia in this group is zero.

in males, the oldest group (61–70 years old), and *APOE* ε4 carriers with <420 min/week of LPA (Table S9).

4. Discussion

This study builds on previous research indicating that higher MVPA levels are associated with lower dementia incidence[1]. Our findings confirm that the MVPA against dementia incidence is dose dependent. Specifically, engaging in more than 300 min/week of MVPA was significantly associated with a lower dementia risk, regardless of whether activity was concentrated within 1–2 days or evenly distributed across the week. Additionally, for those who were unable to achieve the effective MVPA threshold, accumulating 2 h of LPA daily was associated with a lower risk of dementia.

According to the WHO 2020 Guidelines on Physical Activity and Sedentary Behavior, ≥150 min/week of MVPA is a strong recommendation supported by moderate certainty evidence for improving health outcomes [2]. Unlike previous studies that have primarily used the 150 min/week MVPA as a threshold to investigate the relationship between patterns and dementia [11,17], we stratified participants based on the guideline-recommended threshold and identified a more nuanced dose–response relationship (150 min/week of MVPA). Specifically, we found that 150–299 min/week of MVPA was not significantly associated with lower dementia risk, while ≥300 min/week of MVPA was. Our results support a previous Japanese cohort study, which reported that participants who performed ≥ 300 min/week of MPA or 1200 MET-min/week of MVPA had a significantly lower risk of developing suspected dementia than those who did not practice MVPA [18], which suggested that a higher level of MVPA than the WHO's recommendation level may be necessary to effectively reduce dementia risk in older adults.

When analyzing two effective MVPA patterns, we found that effective intensive and effective regular participants had similar all-cause dementia, AD, and VaD incidences. This suggests that performing the same amount of MVPA—whether concentrated 1–2 days or evenly distributed throughout the week—can offer a similar decreased risk of dementia. These results are consistent with a previous study, which also identified that more than 150 min/week was defined as effective MVPA [6]. Meanwhile, similar results were found in studies linking PA patterns to all-cause and cause-specific mortality [17], as well as cardiovascular outcomes [11]. These findings suggest that engagement in MVPA, even if concentrated into 1–2 days per week, benefits health and supports its inclusion in the current PA guidelines. Given that the intensive pattern may be a more convenient option for some individuals, it could help more people achieve the MVPA levels necessary for the prevention of dementia.

Stratification by age revealed minimal benefit of effective MVPA for incident dementia in the 40–50 and 50–60 year age groups at base-

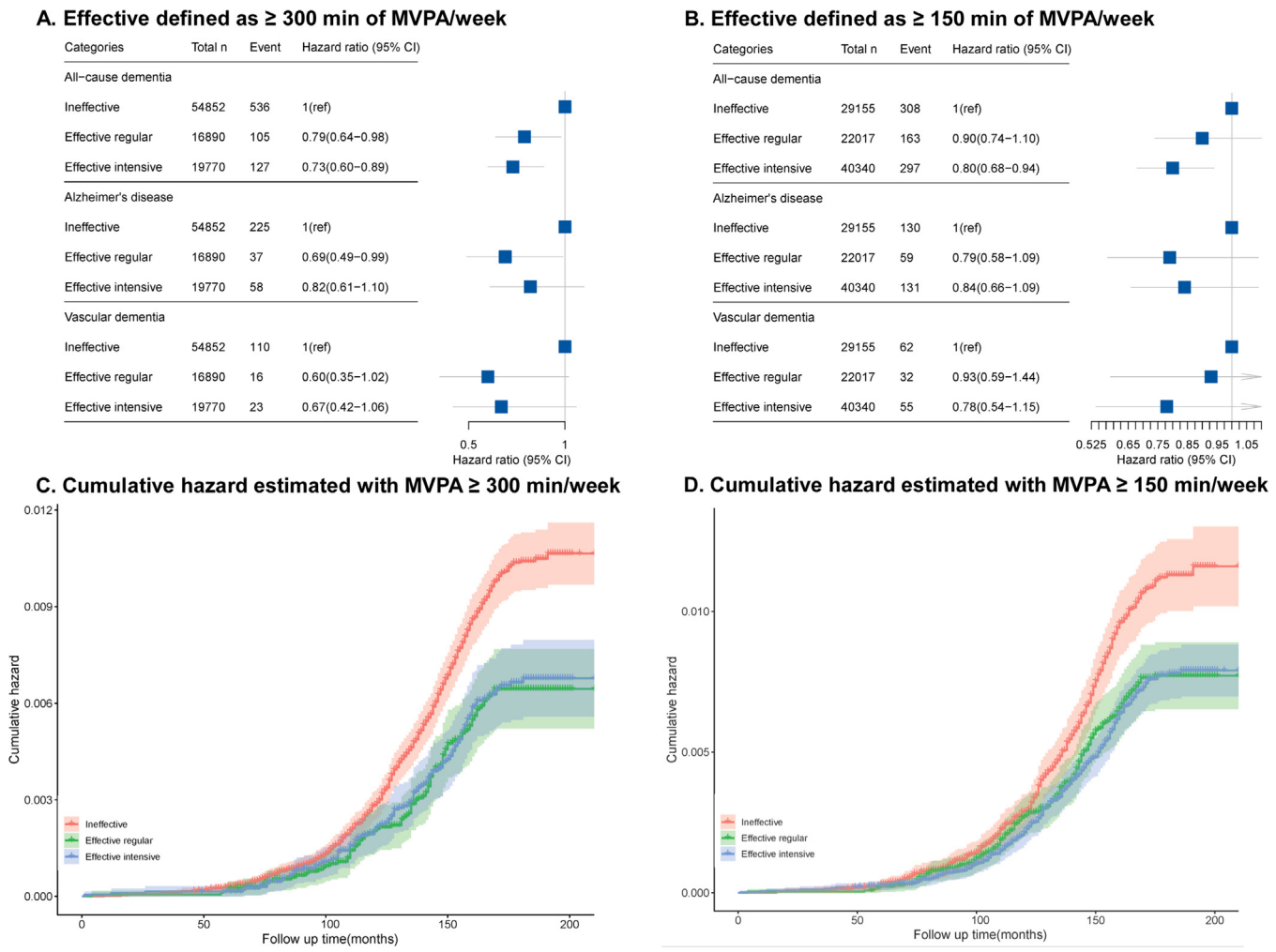

Fig. 3. Associations Between Physical Activity Pattern and Incident Dementia.
(Depicted are plots of multivariable-adjusted associations between activity pattern and incident all-cause dementia, Alzheimer's disease and Vascular dementia. Three activity groups are compared: effective intensive, effective regular, and ineffective (reference). A and B, effective physical activity defined as ≥ 300min/week of MVPA and ≥ 150min/week of MVPA; C and D, the cumulative hazard estimated dementia of three activity pattern at threshold of MVPA ≥300 min/week and ≥150min/week. Bars depict 95 % confidence intervals. MVPA: moderate to vigorous physical activity.

line, likely because their age remained below the high-risk age by the follow-up period [19]. In the oldest age group (61–70 years), effective MVPA, particularly intensive pattern, was beneficial for reducing the incidence of all-cause dementia, indicating that concentrated MVPA may provide more benefits, which was similar to resistance exercise [20]. Stratification by sex showed that MVPA was associated with a low incidence of dementia in females only if it was more than 600 min/week and 300 min/week in males. This may be due to the different impact of the sex factor on dementia incidence [21]. In the MVPA pattern models for female and male groups, a significant association was only found between the effective intensive pattern and dementia incidence, which also indicated that concentrated MVPA may provide more benefits for the prevention of dementia. When stratified analysis by *APOE* genotype, it was interesting that effective MVPA was significantly associated with lower dementia incidence in *APOE* ε4 noncarriers but not in carriers. This suggests that effective MVPA alone may not mitigate the risk associated with *APOE* ε4. Moreover, a significant association was only found between the effective intensive pattern and dementia incidence in *APOE* ε4 noncarriers in the MVPA pattern models. Thus, we not only found the effective levels of MVPA for prevention of dementia in stratification by age, sex and *APOE*, but also the effective intensive pattern was significantly associated with lower incident dementia in the older age group, both female and male, as well as *APOE* ε4 noncarriers. Further research is warranted to explore the specific mechanisms underlying the association between MVPA and other risk factors.

Previous research has shown that LPA confers health benefits after adjusting for MVPA levels [22]. However, the specific benefits of LPA for people who cannot achieve moderate-to-vigorous intensity have not been well documented. In this study, we found that engaging in more than 840 min/week of LPA was associated with all-cause dementia. These findings indicate that LPA could benefit a lower incidence of dementia, even when moderate- or vigorous-intensity activity cannot be achieved. A previous study based on self-reported data found that individuals with approximately 209 min/week of LPA had the lowest risk of developing all-cause dementia [22], which is lower than our findings. Owing to the light intensity, the LPA amount might be substantially understated by the subjective and self-report method [23]. Nonetheless, our results are promising, as engaging in over 2 h/day of LPA can reduce the risk of dementia among many individuals who struggle to achieve MVPA.

5. Limitations

This study has a few limitations. First, the time interval parameter for MVPA was set at <150, 150–299, 300–599, and >600 min/week, which was roughly based on the recommendation (150 min/week) and

Categories	Total n	Event	Hazard ratio (95% CI)	P value
All–cause dementia				
<420 min/week	289	7	1(ref)	
420–839 min/week	917	21	0.68(0.29–1.60)	0.373
840–1259 min/week	4219	42	0.33(0.15–0.74)	0.007
1260–1679 min/week	9574	105	0.39(0.18–0.85)	0.017
1680–2099 min/week	12849	138	0.40(0.19–0.85)	0.018
2100–2519 min/week	12126	109	0.34(0.16–0.73)	0.006
2520–2939 min/week	7746	56	0.29(0.13–0.63)	0.002
>=2940 min/week	7132	58	0.37(0.17–0.83)	0.015
Alzheimer's disease				
<420 min/week	289	2	1(ref)	
420–839 min/week	917	7	0.89(0.18–4.30)	0.883
840–1259 min/week	4219	14	0.42(0.10–1.84)	0.248
1260–1679 min/week	9574	41	0.54(0.13–2.25)	0.401
1680–2099 min/week	12849	61	0.59(0.14–2.42)	0.464
2100–2519 min/week	12126	48	0.48(0.12–1.98)	0.307
2520–2939 min/week	7746	28	0.45(0.11–1.91)	0.279
>=2940 min/week	7132	24	0.48(0.11–2.05)	0.323
Vascular dementia				
<420 min/week	289	3	1(ref)	
420–839 min/week	917	2	0.12(0.02–0.74)	0.022
840–1259 min/week	4219	7	0.11(0.03–0.43)	0.001
1260–1679 min/week	9574	31	0.27(0.08–0.89)	0.031
1680–2099 min/week	12849	17	0.12(0.04–0.42)	0.001
2100–2519 min/week	12126	31	0.26(0.08–0.86)	0.027
2520–2939 min/week	7746	10	0.15(0.04–0.54)	0.004
>=2940 min/week	7132	9	0.17(0.05–0.66)	0.010

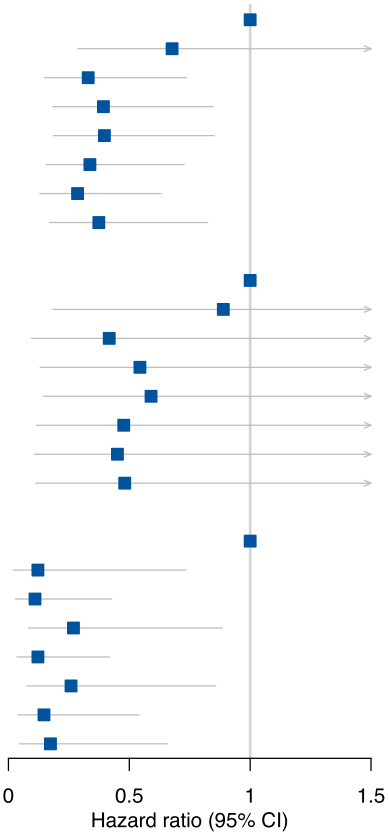

Fig. 4. Dose-response association between LPA and incident dementia.
Depicted are plots of multivariable-adjusted associations between LPA and incident all-cause dementia, Alzheimer's disease and Vascular dementia. Seven groups are compared with the lowest level of LPA. Bars depict 95 % confidence intervals. LPA: light-intensity physical activity. All were adjusted for age (except for subgroup of age), sex (except for subgroup of sex), education, ethnicity, Townsend deprivation index, smoking status, alcohol status, diet quality, diabetes, hypertension, heart attack, stroke, body mass index, and total moderate to vigorous physical activity.

conditional recommendation (300 min/week) in the 2020 Guidelines on Physical Activity and Sedentary Behavior [2]. However, a more precise critical value should be determined through research using large longitudinal cohorts with device-measured PA. Second, PA measurements obtained at a single time, which was a time-varying variable that changed over time. While this approach aligns with cohort study design conventions, the repeated assessments should be considered in future research. Third, the covariates were collected at the baseline, prior to the measurement time of PA. Fourth, the small number of dementia cases was partly due to the younger age of the participants at enrollment. Although the association between effective MVPA and dementia incidence was significant for participants over 50 years, it may not yet be fully apparent in individuals aged 40–50 years.

6. Conclusions

In this large prospective cohort study using wrist-worn accelerometry data, over 300 min/week of MVPA (the conditional recommended threshold in the 2020 WHO Guidelines) was associated with a lower incidence of dementia. Notably, we found that an effective intensive pattern—where most of PA is concentrated within 1–2 days—was associated with a similar lower risk of incident dementia as more evenly distributed regular activity (effective regular pattern). Furthermore, engaging in over 2 h of LPA daily could prevent the incidence of dementia even if one cannot achieve effective MVPA. These findings offer valuable insights into adequate PA levels and patterns for the prevention of dementia, particularly for individuals with limited opportunities for daily or regular PA during the workweek or who struggle to perform MVPA.

Declaration of Competing interests

The authors declare that they have no competing interests.

CRediT authorship contribution statement

Yan Wang: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Fangyu Li:** Writing – original draft, Methodology, Formal analysis, Data curation. **Shuman Cao:** Writing – review & editing, Resources, Methodology, Data curation. **Jianping Jia:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization.

Availability of data and materials

The data that support the findings of this study are available from UK Biobank by application.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tjpad.2025.100223.

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