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Physical Activity Reduces the Incidence of Sarcopenia in Middle-Aged Adults

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Abstract

Purpose of the Research The aim of this study was to investigate associations between physical activity and risk of sarcopenia in middle-aged adults.

Methods This was a longitudinal study based on a subset of UK Biobank data consisting of 1,918 participants (902 men and 1,016 women, mean age 56 years) who had no sarcopenia at baseline based on the criteria of European Working Group on Sarcopenia in Older People (EWGSOP2). The participants were assessed again after 6 years at follow-up, and were categorized into no sarcopenia, probable sarcopenia, or sarcopenia using EWGSOP2. Physical activity was assessed at baseline using 7-day acceleration data that were analysed to obtain physical activity dose at different intensities. Multinominal logistic regression was employed to examine the association between the incidence of sarcopenia and physical activity dose, between baseline and follow up, controlled for other factors at baseline including age, sex, BMI, smoking status, intake of alcohol, vitamin D and calcium, history of rheumatoid arthritis, osteoarthritis, secondary osteoporosis, and type 2 diabetes.

Results Among the 1918 participants with no sarcopenia at baseline, 230 (69 men and 161 women) developed probable sarcopenia and 37 (14 men and 23 women) developed sarcopenia at follow-up. Logistic regression models showed that increase in physical activity dose at moderate-to-vigorous intensity significantly reduced the risk of sarcopenia (odds ratio=0.368, $p<0.05$), but not probable sarcopenia (odds ratio=0.974, $p>0.05$), while physical activity dose at light or very light activity intensity were not associated with the risk of sarcopenia or probable sarcopenia ($p>0.05$).

Conclusions Physical activity at moderate-to-vigorous intensity could reduce risk of sarcopenia in middle-aged adults.

Keywords Ageing · Middle adulthood · Physical activity · Accelerometery · Muscle

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Introduction

Sarcopenia is an ageing-associated musculoskeletal disorder that involves accelerated loss of muscle mass and strength in the older adults. It is associated with adverse outcomes such as increased risks of falls and fractures, reduced mobility, loss of physical function, and death (Cruz-Jentoft et al., 2019). Physical exercise is the recommended intervention to prevent and improve sarcopenia (Park & Roh, 2023). It was also suggested that physical activity intervention should start early in life (e.g. middle-age) to prevent sarcopenia more effectively (Cruz-Jentoft, Alfonso J. & Sayer, 2019).

It may be challenging to implement structured exercise programme for middle-aged adults due to demands of work and family (Caperchione et al., 2012). Compared with structured and repetitive exercise, leisure time physical activity is easy to perform and to continue, which makes it particularly attractive to middle-aged adults (Luo, Jin & Lee, 2021). However, to make the intervention effective it is important to quantify the amount of physical activity in daily activities so that dose response relationship between physical activity and risk of sarcopenia can be established.

A number of previous studies examined the longitudinal association between physical activity and sarcopenia by measuring physical activity using questionnaires (Dodds et al., 2013; Mijnarends et al., 2016), pedometers (Scott et al., 2011), or accelerometers (Shephard et al., 2013). In general, their findings showed that increased amount of leisure time physical activity was associated with greater muscle strength and a lower likelihood of incident sarcopenia (Dodds et al., 2013; Mijnarends et al., 2016; Scott et al., 2011; Shephard et al., 2013). However, it was also found that leisure time physical activity had to reach moderate-to-vigorous intensity to prevent sarcopenia effectively (Mijnarends et al., 2016; Rosique-Esteban et al., 2019; Shephard et al., 2013; Wu et al., 2017). These findings highlight the importance of assessing physical activity objectively so that accurate dose response relationship can be established between physical activity and risk of sarcopenia. As skeletal muscles adapt their structures and masses to mechanical loading, it is necessary to assess the amount of mechanical loading applied to human musculoskeletal system in leisure time physical activities. Previous studies generally used questionnaires and pedometers, and did not provide information about mechanical loading. To this end, we developed methods to objectively assess mechanical loading of physical activity using acceleration data recorded in daily life (Kelley et al., 2014). Although previous work has established the relationship between physical activity and sarcopenia (Chahal et al., 2014; Luo et al., 2018), we do not have a full understanding of the predictive risks of sarcopenia in middle-aged adults when they become older. In particular, further studies are needed to establish dose response relationship between physical activity and prediction of different stages of sarcopenia (probable sarcopenia and sarcopenia) according to the definitions of European Working Group on Sarcopenia in Older People (EWGSOP2) (Cruz-Jentoft et al., 2019).

The aim of this study was to examine associations between leisure time physical activity and predictive risk of sarcopenia in middle-aged adults, using UK Biobank data.

Materials and Methods

Study Design and Population

The current study used longitudinal data from UK Biobank, which is a prospective cohort consisting of around 500,000 UK participants. Out of this cohort, 1,918 participants who had all the variables that we need for this study were selected. Baseline (2006–2010) and follow-up (2014–2018) data were obtained from these participants using the inclusion criteria: (1). participants with data available at both baseline and follow-up on hand grip strength, physical activity, nutrition, and appendicular muscle mass; (2) participants did not have sarcopenia at baseline, as established using their hand grip strength data obtained at baseline (2006–2010) based on the criteria developed by European Working Group on Sarcopenia in Older People (EWGSOP2) (Cruz-Jentoft et al., 2019). According to the criteria, participants with normal grip strength was classified as no sarcopenia.

At the follow-up (2014–2018) we examined the progression of these participants with no sarcopenia into probable sarcopenia and sarcopenia according to the same EWGSOP2 criteria. Participants with low grip strength but normal skeletal muscle index (SMI, calculated as appendicular lean mass divided by squared body height) was classified as probable sarcopenia, whereas those with low grip strength and low SMI was classified as sarcopenia.

We also studied the physical activity level (2013 to 2015) and nutrition intake (2009 to 2012) of these participants between baseline and follow-up.

Data Obtained From UK Biobank

Data obtained at both baseline and follow-up included participants' age, sex, weight, height, body mass index (BMI), hand grip strength, and self-completed questionnaire data including smoking status (never, previous, or current smoker), history of rheumatoid arthritis (yes or no), osteoarthritis (yes or no), secondary osteoporosis (yes or no), and type 2 diabetes (yes or no), as these conditions were found to be associated with sarcopenia in previous research (Ho et al., 2021; Argyropoulou et al., 2022; Torii et al., 2019). Arm lean mass and leg lean mass were obtained at follow-up from dual energy X-ray absorptiometry (DXA) assessment of body composition conducted on participants. Appendicular lean mass was then derived as the sum of arm lean mass and leg lean mass.

Physical activity data were obtained from 7-day raw acceleration data measured by a wrist-worn triaxial accelerometer Axivity AX3 (Axivity Ltd, UK). The accelerometer was set to sample acceleration data at 100 Hz with a dynamic range of ±8 g. The quality of the raw acceleration data from each participant had been checked by UK Biobank. Only acceleration data that fulfilled UK Biobank data quality requirements were used in this study.

Nutrition data were obtained from UK Biobank dietary assessment conducted through an on-line dietary questionnaire that collected information on the quantities of all food and drinks consumed over the previous day (Greenwood et al., 2019). The questionnaire takes 10–15 min to complete. It contains questions on the frequency

of consumption of about 200 commonly consumed foods and drinks as well as on the consumption of meals outside the home. Replies can be coded automatically to calculate estimated daily nutrient intake (Perez-Cornago et al., 2021). Four rounds of online questionnaire were conducted, with invitation being emailed to participants at 3–4 monthly intervals. The current study used the average value of the estimated daily nutrient intake of Vitamin D, calcium, and alcohol from the four rounds.

Data Analysis

Raw acceleration data were analysed to quantify the amount of mechanical loading in participants' physical activity using the methods developed in previous research (Kelley et al., 2014). The data were first uploaded into Open Movement AX3 OMGUI (version 1.0.0.30, Newcastle University, UK) to extract 12-h (8 a.m. to 8 p.m.) acceleration data from each day. The extracted data were then analysed using a customized MATLAB program (Mathworks Inc, Natick, MA, USA) to obtain dose of physical activity. Firstly, the 12-h acceleration data were resampled at 20 Hz. Resultant acceleration was then calculated and then filtered using a Butterworth band pass filter (0.1–6 Hz). The 12-h acceleration data were then split into 8,640 consecutive segments, each 5-s long. Physical activity intensity for each segment was then calculated using Fast Fourier transformation as

$$LI = \sum_{fi=0.1}^{6Hz} (Ai \times fi)/g$$

where *LI* is physical activity intensity normalized to body weight (BW/s), *Ai* is acceleration (m/s^2) at frequency *fi*, and *g* is gravitational acceleration (9.81 m/s^2).

Dose of physical activity during the 12-h period was then calculated at three intensity categories - very light (LI<5 BW/s), light (5 BW/s< LI<10 BW/s), moderate-to-vigorous (LI>10 BW/s) as

$$LD = \sum_{8640} 5 \times LI$$

where *LD* is physical activity dose (BW), and LI physical activity intensity (BW/s) (Chahal et al., 2014; Kelley et al., 2014).

Physical activity dose calculated from each day were then averaged across 7 days as the measurement of physical activity for each participant.

Statistical Analysis

Independent t-test, paired t-test, and Chi-squared test were used to compare characteristics between men and women, and between baseline and follow-up.

Multinominal logistic regression with stepwise method was employed to examine the association of incident probable sarcopenia and sarcopenia at follow-up with physical activity, nutrition intake, and other risk factors assessed at baseline, includ-

ing age, sex, BMI, smoking status, intake of alcohol, rheumatoid arthritis, osteoarthritis, secondary osteoporosis, and type 2 diabetes.

Multiple linear regression analysis with stepwise method was employed to examine the association of hand grip strength, arm lean mass, and leg lean mass measured at follow-up with physical activity, nutrition intake and other risk factors assessed at baseline, including age, sex, BMI, smoking status, intake of alcohol, rheumatoid arthritis, osteoarthritis, secondary osteoporosis, and type 2 diabetes. Multi-collinearity between independent variables was checked by variance inflation test (VIF<10).

For all statistical analysis SPSS 28.0 (IBM, Armonk, NY, USA) was used. Statistical significance was determined when p value was less than 0.05.

Results

In total 1,918 participants (902 men and 1,016 women) fulfilled the inclusion criteria and were included in the study. The ethnic background for majority of participants is white (98.1%). The average length between baseline and follow-up was 6.1±0.9 years (range from 4.3 to 8.3 years). Characteristics of participants at baseline and follow-up were shown in Table 1. Among the 1,918 participants with no sarcopenia at baseline 230 (69 men and 161 women) developed probable sarcopenia, and 37 (14 men and 23 women) developed sarcopenia at follow-up. The incidence rate from baseline to follow-up was significantly higher in women for both probable sarcopenia (15.8% vs. 8.0%, $p<0.05$) and sarcopenia (2.3% vs. 1.6%, $p<0.05$). Hand grip strength decreased significantly by 12.7% in men and 15.5% in women from baseline to follow-up ($p<0.05$). The amount of moderate-to-vigorous physical activ-

Table 1 Characteristics of participants at baseline and follow-up (mean±S.D.)

	Baseline		Follow-up	
	Men (*n*=902)	Women (*n*=1,016)	Men (*n*=902)	Women (*n*=1016)
Age (yrs)	56.9±7.2	54.6±7.4	62.4±6.8	60.4±7.2
Weight (kg)	85.1±13.4	69.9±12.7*	84.2±13.4	69.5±12.9*
Height (cm)	176.7±6.3	163.6±6.2*	176.3±6.3	163.1±6.2*
BMI (kg/m^2)	27.2±3.8	26.1±4.6*	27.1±3.9	26.1±4.8*
Hand grip strength (kg)	41.5±7.8	25.1±5.3*	36.2±7.9$^{\nabla}$	21.2±5.4*$^{\nabla}$
Current smoker	60/902	45/1016*	44/897	22/1007*
Previous smoker	335/902	349/1016*	345/897	351/1007*
rheumatoid arthritis (yes)	4/902	7/1016	6/902	12/1016
Osteoarthritis (yes)	42/902	62/1016	27/902	59/1016*
secondary osteoporosis (yes)	9/902	23/1016*	17/902	36/1016*
type 2 diabetes (yes)	3/902	3/1016	17/902	14/1016
Appendicular lean mass (g)			25685.5±3530.5	17538.7±2608.9*
Arm leam mass (g)			6772.1±984.9	4130.5±637.4*
Leg lean mass (g)			18913.5±2648.0	13408.2±2052.7*
No sarcopenia	902	1016	819	832
probable sarcopenia	0	0	69	161*
Sarcopenia	0	0	14	23*

Note *: $p<0.05$ compared with men; ∇, $p<0.05$ compared with baseline

Table 2 Physical activity and nutrition intake of participants (mean±S.D.)

	Men (*n*=902)	Women (*n*=1,016)	*P* value
MVPA loading dose (BW)	1655.7±3785.1	940.9±2315.4	<0.001
LPA loading dose (BW)	3153.5±2577.9	2990.2±2238.1	0.069
VLPA loading dose (BW)	36708.4±8283.3	39800.5±8145.6	<0.001
Vitamin D (μg)	3.2±2.8	2.8±2.6	0.005
Calcium (mg)	1021.5±364.9	975.7±362.7	0.006
Alcohol (g)	23.2±24.6	11.3±14.3	<0.001

Note MVPA=moderate-to-vigorous physical activity (loading intensity ≥ 10 BW/s); LPA=light physical activity (5 BW/s ≤ loading intensity<10 BW/s); VLPA=very light physical activity (loading intensity<5 BW/s)

Table 3 Association between risk factors and incidence of probable Sarcopenia and Sarcopenia (*N*=1,918)

Predictive factor	B (S.E.)	Odds ratio [95% Confidence interval]	*p* value
Probable sarcopenia vs. no sarcopenia			
Constant	-6.751 (0.810)		<0.001
Sex (men as reference)	0.950 (0.157)	2.586 [1.901, 3.517]	<0.001
Age (years)	0.066 (0.011)	1.068 [1.046, 1.090]	<0.001
BMI (kg/m^2)	0.02 (0.016)	1.02 [0.988, 1.053]	0.225
MVPA loading dose (1000×BW)	-0.026 (0.35)	0.974 [0.910, 1.042]	0.443
Sarcopenia vs. no sarcopenia			
Constant	6.878 (2.088)		<0.001
Sex (men as reference)	-0.342 (0.374)	0.711 [0.341, 1.480]	0.361
Age (years)	0.019 (0.024)	1.019 [0.972, 1.069]	0.428
BMI (kg/m^2)	-0.450 (0.069)	0.638 [0.557, 0.730]	<0.001
MVPA loading dose (1000×BW)	-1.000 (0.393)	0.368 [0.170, 0.794]	0.011

Note R^2=0.073 (Cox & Snell) 0.121 (Nagelkerke). Model $c^2(8)$=145.110, p<0.001

Variable code for sarcopenia category (0=no sarcopenia, 1=probable sarcopenia, 2=sarcopenia). MVPA=moderate-to-vigorous physical activity (loading intensity ≥ 10 BW/s); LPA=light physical activity (5 BW/s ≤ loading intensity<10 BW/s); VLPA=very light physical activity (loading intensity<5 BW/s)

ity (MVPA) was higher in men, while women had higher dose in very light physical activity (VLPA) (p<0.05) (Table 2). No significant difference was found in dose of light physical activity (LPA) between men and women (p>0.05). The intake of Vitamin D, calcium, and alcohol was higher in men (p<0.05).

The multiple logistic regression model showed that increase in MVPA dose and BMI could significantly reduce the incidence of sarcopenia (p<0.05), while LPA or VLPA did not have any significant association with the incidence of sarcopenia. On the other hand, advancing age and being women significantly increase the risk of probable sarcopenia (p<0.05), while physical activity did not have any significant association with the incidence of probable sarcopenia (p>0.05) (Table 3). Other factors such as smoking status, intake of alcohol, Vitamin D, and Calcium, history of rheumatoid arthritis, osteoarthritis, secondary osteoporosis, and type 2 diabetes did not have significant effect on incidence of probable sarcopenia or sarcopenia (p>0.05).

Age, being women, and greater amount of VLPA was associated with lower hand grip strength at follow-up (Table 4). LPA was positively associated with hand grip

Table 4 Association between risk factors and hand grip strength measured at follow-up (*N*=1,918)

	B (S.E.)	β	*p* value
Constant	32.723 (1.791)		<0.001
Sex	15.268 (0.309)	0.758	<0.001
Age	-0.245 (0.020)	-0.180	<0.001
BMI (kg/m^2)	0.135 (0.036)	0.058	<0.001
Type 2 diabetes	-7.771 (2.634)	-0.043	0.003
Osteoarthritis	-2.390 (0.649)	-0.054	<0.001
LPA loading dose (1000×BW)	0.241 (0.076)	0.058	0.001
VLPA loading dose (1000×BW)	-0.051 (0.022)	-0.042	0.022

Note Model R^2=0.6, p<0.001. Variable code for sex (0=women, 1=men). MVPA=moderate-to-vigorous physical activity (loading intensity ≥ 10 BW/s); LPA=light physical activity (5 BW/s ≤ loading intensity<10 BW/s); VLPA=very light physical activity (loading intensity<5 BW/s)

Table 5 Association between risk factors and arm lean mass measured at follow-up (*N*=1,918)

	B (S.E.)	β	*p* value
Constant	2287.788 (194.659)		<0.001
Sex	2586.998 (33.191)	0.833	<0.001
Age	-21.741 (2.176)	-0.104	<0.001
BMI	100.204 (3.823)	0.278	<0.001
Calcium	0.151 (0.043)	0.036	<0.001
LPA loading dose	24.056 (8.133)	0.037	0.003
VLPA loading dose	4.758 (2.397)	0.026	0.047

Note Model R^2=0.806, p<0.001. Variable code for sex (0=women, 1=men). MVPA=moderate-to-vigorous physical activity (loading intensity ≥ 10 BW/s); LPA=light physical activity (5 BW/s ≤ loading intensity<10 BW/s); VLPA=very light physical activity (loading intensity<5 BW/s)

strength and arm lean mass (Tables 4 and 5), while MVPA was positively associated with leg lean mass (Table 6).

Discussion

To our knowledge, this is the first longitudinal study of associations between accelerometer-determined physical activity and the incidence of sarcopenia in middle-aged adults according to the revised EWGSOP2 definition. Our study showed that moderate-to-vigorous physical activity was significantly associated with reduced progression from no sarcopenia to sarcopenia, but did not have significant influence on the progression to probable sarcopenia. It is clear that physical activity has positive effect on the incidence of sarcopenia.

Our findings were consistent with previous longitudinal studies that examined the association of physical activity and the incidence of sarcopenia. Mijnarends et al. (2016) used a self-reported questionnaire to assess physical activity in older adults (mean age 75 years). The authors identified sarcopenia using the original 2010 EWGSOP definition (EWGSOP1). It was found that participants reporting a moderate to high amount of MVPA had a significantly lower likelihood of incident sarcopenia over a 5-year period (Mijnarends et al., 2016). Similarly, another study using EWGSOP1

Table 6 Association between risk factors and leg lean mass measured at follow-up (*N*=1,918)

	B (S.E.)	β	*p* value
Constant	8968.036 (431.771)		<0.001
Sex	5298.827 (86.836)	0.732	<0.001
Age	-80.209 (5.792)	-0.164	<0.001
BMI (kg/m^2)	318.548 (9.928)	0.380	<0.001
Calcium (g)	0.459 (0.115)	0.046	<0.001
MVPA loading dose (1000×BW)	40.624 (13.795)	0.035	0.003

Note Model R^2=0.746, p<0.001. Variable code for sex (0=women, 1=men). MVPA=moderate-to-vigorous physical activity (loading intensity ≥ 10 BW/s); LPA=light physical activity (5 BW/s ≤ loading intensity<10 BW/s); VLPA=very light physical activity (loading intensity<5 BW/s)

also found that physical activity levels assessed using questionnaire were associated with the development of sarcopenia from baseline to 4-year follow-up in older adults (mean age of 73 years) (Yu et al., 2014). A longitudinal study using accelerometer to measure physical activity also found that a longer duration of habitual physical activity at an intensity more than 3 metabolic equivalents (METs) significantly decreased the risk of developing sarcopenia in older adults aged 65 to 84 (Shephard et al., 2013). Findings from a number of cross-sectional studies also showed that physical activity at moderate-to-vigorous intensity was associated with reduced sarcopenia in the middle-aged and older adults (Rosique-Esteban et al., 2019; Scott, David et al., 2021; Takeshima et al., 2004). It is clear from these findings that intensity of physical activity plays a crucial role in the prevention of sarcopenia, and it should be measured objectively for establishing accurate dose response relations. Previous studies have used various methods to assess physical activity intensity, including subjective (e.g. questionnaires) and objective methods (e.g. accelerometers). In comparison, the current study employed the method that could quantify intensity of physical activity based on the measurement of mechanical loading. This may provide a more accurate way to study the relation between physical activity and sarcopenia as mechanical loading was a key factor that determines the structure and function of muscles. Indeed, our results showed that only moderate-to-vigorous physical activity was positively associated with leg lean mass, which explains why MVPA has positive effect on the incidence of sarcopenia.

To the best of our knowledge there is only one previous study that examined the association of physical activity with incidence of probable sarcopenia. The study found no significant association between four-year incidence of probable sarcopenia and physical activity levels assessed by questionnaire in older adults over 60 years (Chen et al., 2022). This is in line with cross-sectional studies which found no significant associations between physical activity and probable sarcopenia (Zhao et al., 2023) or between MVPA and hand grip strength in middle-aged adults (45–64 years) (Cooper et al., 2017). However, a study using data from the British National Survey of Health and Development (the 1946 birth cohort) has shown that increased leisure time physical activity across mid-life were associated with stronger grip strength at age 60–64, in both men and women (Dodds et al., 2013).

To understand this further, we examined the association between physical activity and hand grip strength, arm lean mass, and leg lean mass. We found that both hand grip strength and arm lean mass were significantly associated with LPA. On

the other hand, leg lean mass was significantly associated with MVPA. According to EWGSOP2 probable sarcopenia is mainly defined by low hand grip strength, while sarcopenia is confirmed when people with probable sarcopenia progressed to have low appendicular muscle mass (Cruz-Jentoft et al., 2019). As appendicular muscle mass includes both the upper and the lower body muscles, its association with physical activity may reflect the difference between the two muscle groups and how they respond to physical activity at different intensities.

Previous studies found that the correlations between hand grip strength and knee extension strength were low in healthy young and healthy older individuals (Yeung et al., 2018). It was also found that the strength and power of lower body muscles declined faster during ageing compared to upper body muscles (Hughes et al., 2001). It is possible that physical activity with higher intensity is needed to counteract the faster decline of strength in the lower body muscles. This argument is supported by previous findings that MVPA tended to have weak or no association with hand grip strength but had stronger association with leg muscle strength in the middle-aged and older adults (Cooper et al., 2017; Ramsey et al., 2021). Our findings highlight the importance of intensity when designing physical activity interventions to prevent sarcopenia in the middle-aged.

In the current study the annual incidence rate was found to be 2% for probable sarcopenia and 0.3% for sarcopenia. These figures are comparable to a previous study using EWGSOP1 definition, which found that the annual incidence rate was 2.3% for probable sarcopenia and 0.4% for sarcopenia in 518 participants with mean age of 60 years (Gielen et al., 2015). Other studies with older participants tended to have higher annual incidence rate, which was around 10% for probable sarcopenia (Chen et al., 2022) and 3% for sarcopenia (Mijnarends et al., 2016; Yu et al., 2014, 2020). This is consistent with previous finding that incidence of sarcopenia increases with age. Similarly, the prevalence of sarcopenia also increases with age, which was 1.9% in the current study in comparison to 4.4–14.2% in previous studies with older participants (Mayhew et al., 2019; Rosique-Esteban et al., 2019; Trajanoska et al., 2018). However, the findings of this study clearly demonstrate the lack of physical activity (and other risk factors) may accelerate sarcopenia as we get older.

Previous studies found that deficiency in Vitamin D and calcium was associated with higher risk of sarcopenia in older adults (Seo et al., 2013; Remelli et al., 2019). Similar to these findings, the current study found that calcium intake was significantly associated with arm lean mass and leg lean mas. However, our study didn't find any significant association between intake of Vitamin D and calcium and incidence of sarcopenia in middle-aged adults.

There are some limitations in our study. We couldn't examine the effect of physical activity on the progression from probable sarcopenia to sarcopenia due to the lack of muscle mass data at baseline to categorise participants. Another limitation is that we didn't study the intake of protein in our analysis due to the lack of data.

Our results showed that the odds ratio of incident sarcopenia due to the change of MVPA was 0.368 (Table 3). This suggests that increase of MVPA dose by 1,000 BW per day is associated with a three-fold decrease in the risk of developing sarcopenia. If we use the intensity threshold of MVPA at 10 BW/s as the average intensity, this is equivalent to around 2 min (100 s) of moderate-to-vigorous physical activity every

day. However, a previous study found that to reduce the risk of developing sarcopenia by three times, 15 to 20 min of habitual physical activity at an intensity greater than 3 metabolic equivalents (METs) is needed (Shephard et al., 2013). The difference may be due to the different methods used to quantify intensity of physical activity. It may also be due to that participants in our study are middle-aged adults, while older participants aged over 65 years were used in that previous study. The finding may suggest that engaging in physical activity at mid-life is a more effective way at preventing sarcopenia.

In conclusion, the current study found that moderate-to-vigorous physical activity was significantly associated with reduced incidence of sarcopenia in middle-aged adults. Our results suggest that exercise interventions with appropriate intensity should be employed to prevent sarcopenia in middle-aged adults.

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Declarations

Ethical Approval This research has been conducted using the UK Biobank Resource (project ID 23804). UK Biobank has approval from the North West Multi-centre Research Ethics Committee (MREC), which covers the UK. It also sought the approval in England and Wales from the Patient Information Advisory Group (PIAG) for gaining access to information that would allow it to invite people to participate. It does not require further ethics approval by the institutions.

Consent to Participate Obtained by UK Biobank.

Consent for Publication Obtained by UK Biobank.

Competing Interests All authors declare no competing interests.

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