Accelerometer-measured light-intensity physical activity and the risk of cardiovascular disease or death in older adults: A meta-analysis

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ABSTRACT

Background: Light-intensity physical activity (LPA) is related to a reduced risk of all-cause death in older adults, but its effect on cardiovascular disease or death remains questioned. This meta-analysis aimed to quantify the association of LPA with the risk of cardiovascular disease and death in older adults.

Methods: We conducted a literature search in electronic databases for prospective cohort studies assessing the relationship between LPA measured by accelerometers and the risk of cardiovascular disease and/or death in adults aged ≥60 years. Study-specific hazard ratios (HRs) and 95% confidence intervals (CIs) were pooled using a random effects model.

Results: Of the 518 articles identified, 5 prospective cohort studies were included. The mean body mass index of included participants was all over 25 kg/m^2. Pooled results showed that the summary HR per 60 min/day higher of LPA was 0.90 (95% CI, 0.83–0.98; n = 3) for the risk of cardiovascular disease and 0.59 (95% CI, 0.49–0.72; n = 2) for cardiovascular death. Both the relationship of LPA with the risk of cardiovascular disease and cardiovascular death were linearly and inversely shaped. The HR for the risk of cardiovascular disease was greater for LPA than for moderate-to-vigorous physical activity (MVPA), in either equal time or equal amount scale (both $P_{interaction}$ <0.01); but the HR for the risk of cardiovascular death was comparable between LPA and MVPA in both scales (both $P_{interaction}$ ≥0.20).

Conclusions: Higher LPA is associated with a reduced risk of cardiovascular disease and death in older adults.

Key words: accelerometer, cardiovascular disease, light-intensity physical activity, moderate-to-vigorous physical activity, older adults

INTRODUCTION

Current physical activity guidelines have consistently recommended a minimum of 150 min/week of moderate-to-vigorous physical activity (MVPA) to improve or maintain cardiovascular health in older adults aged over 60 years [1–3]. However, there has been a lack of emphasis on the preventive benefit of light-intensity physical activity (LPA), which represents the major form of daily physical activities, particularly in older adults who present with an increased risk of cardiovascular disease or death and are less likely to perform physical activities at higher intensities [2, 4, 5]. Understanding the potential of LPA in reducing the risk of cardiovascular disease or death may, therefore, modify health recommendations for older adults.

WHAT'S NEW?

Current guidelines recommend older adults engage in ≥150 min/week of moderate-to-vigorous physical activity (MVPA) or ≥75 min/week of vigorous-intensity physical activity (VPA) to gain cardiovascular benefits. However, none of the guidelines issued for older adults emphasize the cardio-protective benefit of light-intensity physical activity (LPA), which is the predominant component across the spectrum of physical activity in one's daily life and is probably the most attainable category of physical activity for older adults. In this study, we found that LPA was related to a reduced risk of cardiovascular disease and death and was comparable to MVPA in decreasing the risk of cardiovascular death in older adults. This indicates that LPA should be routinely recommended for older adults, and advice on how to promote LPA should be integrated into clinical practice.

Previous studies have extensively investigated the benefits of MVPA assessed by questionnaires for reducing the risk of cardiovascular disease or death [3, 6–9]. Yet very few of them have focused on LPA [8, 9], which might be attributable to the fact that questionnaires could not document the accumulation of LPA accurately and might be subject to recall bias [10], at least partly. However, owing to the development of accelerometers, which could measure LPA in an accurate and objective manner, there has been a growing interest in investigating the association of objectively-measured LPA with the risk of cardiovascular disease or death in recent years [11–17]. However, inconsistent outcomes were reported [11–15], with most of them suggesting that LPA cannot lower the risk of cardiovascular disease in older adults [12–14], in particular, after controlling for MVPA [12, 13]. Moreover, a recent study noted that in the context of a given amount of physical activity (calculated as intensity × time), MVPA led to a larger risk reduction in all-cause death than LPA [18], indicating that the intensity of physical activity might matter more than its amount in reducing the risk of all-cause death. Yet it is unclear whether this could be generalized to risk reduction in cardiovascular disease or death in older adults.

As such, we conducted this meta-analysis, aiming to address these concerns by summarizing and quantifying the available evidence on accelerometer-measured LPA and the risk of cardiovascular disease or death in older adults.

METHODS

Data sources and inclusion criteria

This meta-analysis was based on the guidelines of the Meta-analysis of Observational Studies in Epidemiology (Supplementary material, *Table S1*). We performed a literature search in PubMed and Scopus before January 5, 2021, which was updated on March 19, 2022, using terms or words related to light-intensity physical activity, accelerometers, and cardiovascular disease (Supplementary material, *Table S2*). The detailed search strategy was created based on previous meta-analyses. We also manually checked the reference lists from eligible studies to identify other potentially relevant studies. Since this study was a systematic review and meta-analysis summarizing and quantifying evidence based on published studies, ethical approval was not required.

In this meta-analysis, studies considered eligible for inclusion (1) targeted older adults aged at least 60 years; (2) measured light-intensity physical activity based on accelerometers (accelerometers have uniaxial motion sensors detecting vertical acceleration with activity-intensity transformed as count values [10], e.g., Actigraph GT3X+ [Actigraph, Pensacola, FL, US] defined light-intensity as 100–1040 counts per minute [12]); (3) had prospective cohort design; (4) provided risk estimates (e.g., hazard ratio [HR] and 95% confidence intervals [CIs]) on cardiovascular disease and/or death; and (5) were published in English-language. Studies were excluded if they enrolled a population aged below 60 years, assessed physical activity by questionnaires, were cross-sectional studies or conference abstracts, or had no outcomes of interest (e.g., reported data on cardiovascular risk factors instead). For the study that provided outcomes on both coronary heart disease and cardiovascular disease [13], priority was given to data on cardiovascular disease since it has a broader definition than coronary heart disease [19].

Data extraction and assessment of study quality

All retrieved publications were managed by Endnote X7 to screen for suitable studies. For each included study the following information was extracted using a pre-designed Excel sheet: first author, publication year, name and origin of the cohort, characteristics of participants such as reported mean age, body mass index, sex, mean follow-up duration, number of participants and incident cases, LPA definition and its cut-off point, brand information for used accelerometers, effect estimates for cardiovascular outcomes, and adjusted covariates.

Study quality was assessed using the Newcastle Ottawa Scale that targets 3 major domains: selection of study cohorts (4 sub-items), comparability of study cohorts (one item), and the assessment of outcomes of interest (3 sub-items). A maximum of 9 stars can be awarded to each study, and we considered studies of ≥7 stars high quality [20].

All data extraction and the assessment of study quality were initially carried out by SQ but were later checked by BX. Discrepancies were resolved by referring back to original studies and discussion with XC (the third investigator).

Data synthesis and statistical analysis

Study-specific multivariable-adjusted HRs and 95% CIs per 60 min/day higher of LPA for cardiovascular disease and death were pooled using a random-effects meta-analysis model, which provides more conservative results and better accounts for heterogeneity compared with the fixed-effects meta-analysis model [21]. For studies that treat LPA as the categorical variable, their HRs and corresponding 95% CIs per 60 min/day higher of LPA were computed based on the generalized least squares for the trend estimation method. For this, the median was considered equal to its mean or calculated as the average of the upper and lower boundaries when LPA was reported in ranges. If the lowest or highest boundary of LPA was not specified, we assumed that the width of this category was the same as that of its neighboring category [22]. Moreover, for the studies that split LPA into low and high groups, their data were combined into a single one using a fixed-effects model to be consistent with other studies.

To further analyze the association of LPA with the risk of cardiovascular disease and death, dose-response analyses were conducted according to the approach proposed by Greenland and Longnecker [23]. And the nonlinear relationship was investigated using the restricted cubic splines with three knots at the 10th, 50th, and 90th percentiles of LPA, along with the test to assess whether the coefficient of the second spline is equal to zero.

For the comparisons between LPA and MVPA, we defined the intensity of LPA as 2.3 metabolic equivalents (METs) and 5 METs for MVPA [24]. The amount of MVPA and LPA used for comparison was set to be "150 min × MET/day", given that 30 min/day of MVPA is the recommended amount of physical activity for health promotion by most guidelines [2, 25]. In this meta-analysis, all analyzes on MVPA were generally identical to those on LPA. To assess whether the benefit of LPA was independent of MVPA, we conducted separate analyses by pooling study-specific HRs adjusted for MVPA, in addition to the primary outcome focused on HRs without adjustment for MVPA.

Heterogeneity was quantified by I^2 statistic, and an I^2 value ≥50% was considered significant heterogeneity. In this meta-analysis, publication bias was not assessed because the number of included studies was rather small. All statistical analyses were performed using STATA (Version 14.0, StataCorp LP, College Station, TX, US), and a *P*-value <0.05 was considered statistically significant unless otherwise indicated.

RESULTS

Literature search and study characteristics

The flowchart of the literature search and study selection is shown in Figure 1. Out of the identified 518 articles (113 from PubMed and 405 from Scopus), 103 duplicates were removed. Upon the evaluation of titles, abstracts, and full texts, a total of 410 articles were further excluded, for the reasons listed in Figure 1. As a result, 5 studies were finally included in this meta-analysis [11–15].

The characteristics of included studies are shown in Table 1. A total of 766 cases of cardiovascular disease from 10 385 participants in 3 cohorts [11–13] and 292 cases of cardiovascular death from 9300 participants in 2 cohorts [14, 15] were reported. The mean ages for enrolled participants from individual studies were over 70 years old, and their mean body mass index was greater than 25.0 kg/m^2, indicative of overweight or obesity. All the included studies were conducted in Western countries, with 3 in the US and 2 in European countries (1 in Sweden and 1 in the United Kingdom).

The accelerometer brand — Actigraph GT3X+ (Actigraph, Pensacola, FL, US) was most commonly employed for LPA measurement, but in the study by Ensrud et al. [14], SenseWear Pro Armband (BodyMedia, Inc., Pittsburgh, PA, US) was used. The definition for LPA varied across studies and different scales were reported, in particular, in the study by Ensrud et al. [14] who defined LPA as 1.51–2.99 MET instead of using readings of 'counts per minute'. All studies were judged to be of good quality.

Outcomes for cardiovascular disease in relation to LPA and MVPA

All 3 studies on cardiovascular disease [11–13] reported a significant reduction in the risk of cardiovascular disease in relation to increased LPA in the model that adjusted for the fewest covariables. However, their magnitudes were decreased when the number of adjusted covariables was increased, in particular, after controlling for MVPA. For example, in studies that provided outcomes with adjustment for MVPA [12, 13], risk reduction in cardiovascular disease associated with LPA became all non-significant.

After pooling all the data together, the summary HR for the risk of cardiovascular disease per 60 min/day higher of LPA was 0.90 (95% CI, 0.83–0.98; Figure 2A) without adjustment for MVPA, but it weakened to be 0.93 (95% CI, 0.86–0.995) with statistical significance after adjustment for MVPA. Dose-response analysis showed that there was no evidence of a non-linear relationship between LPA and the risk of cardiovascular disease ($P_{nonlinearity}$ = 0.21), and the curve was inversely shaped (Supplementary material, *Figure S1A*).

Three studies reported data on LPA and MVPA, and comparisons suggested that the magnitude of risk reduction was less for LPA than MVPA (both $P_{interaction}$ <0.01), in both equal time (set at per 60 min/day increase, Figure 2A) and equal amount scales (set at per 150 min × MET/day increase, Figure 2B).

Outcomes for the relation of LPA and MVPA to cardiovascular death

Out of the 2 studies on cardiovascular death [14, 15], one found that LPA was not associated with the reduced risk of cardiovascular death in men [14], but the other revealed

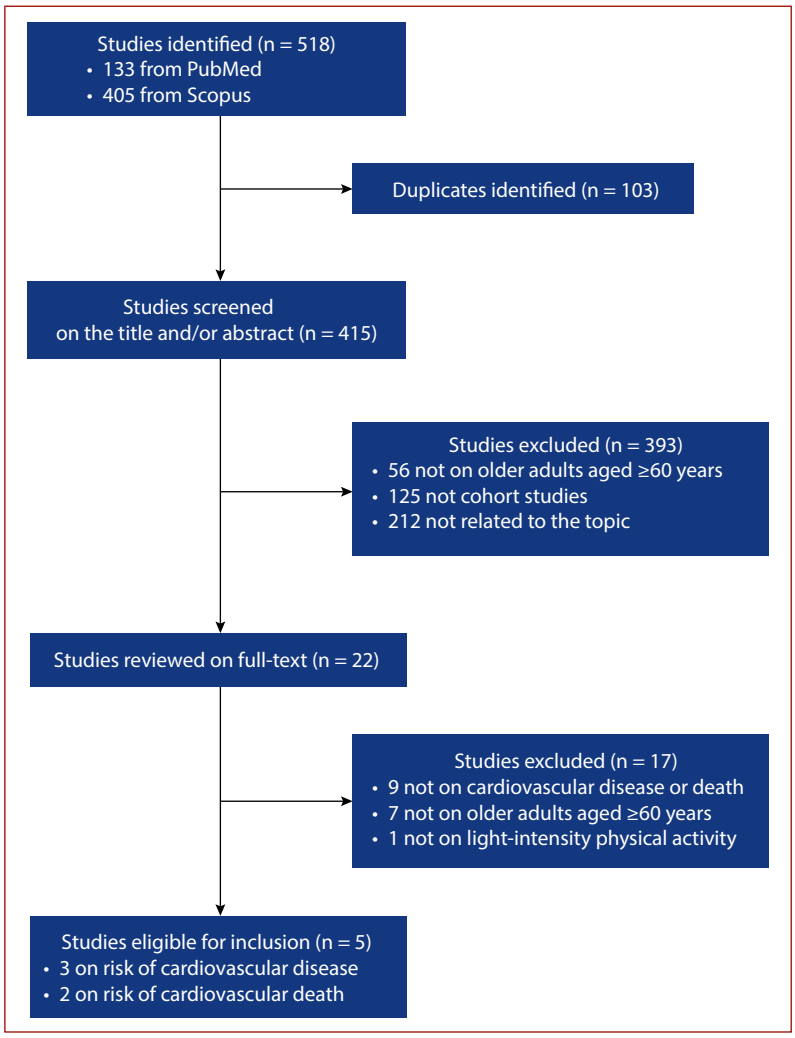

Figure 1. Flowchart of study search and selection

a significant association in older women, in particular for the high-LPA group [15]. The pooled HR for the risk of cardiovascular death per 60 min/day higher of LPA was 0.59 (95% CI, 0.49–0.72; Figure 3A), while none of the included studies had controlled for MVPA. Dose-response analysis suggested that there was no evidence of departure from linearity regarding the relationship of LPA with the risk of cardiovascular death ($P_{nonlinearity}$ = 0.74, Supplementary material, *Figure S1B*).

Further analysis showed that the magnitude of risk reduction in cardiovascular death was comparable between LPA and MVPA (both $P_{interaction}$ ≥0.20), regardless of equal time (Figure 3A) or equal amount scale (Figure 3B).

DISCUSSIONS

Main findings

Our study is the first meta-analysis that synthesized the evidence on the association of LPA with the risk of cardiovascular disease and death in older adults, which showed that a 60 min/day higher amount of LPA resulted in a risk reduction of 10% for cardiovascular disease and 41% for cardiovascular death. Moreover, despite a lower efficacy compared with MVPA in reducing the risk of cardiovascular disease, LPA was shown to be comparable to MVPA in lowering the risk of cardiovascular death.

Interpretations and implications

Previous meta-analyses have consistently suggested that the time spent in LPA is related to the reduced risk of all-cause mortality in either general or older populations [26–28]. As a supplement to these findings, our meta-analysis supports the potential of LPA for promoting cardiovascular health, which might be independent of MVPA in older adults. The majority of older adults, in particular, those overweight or with obesity, are physically inactive, show impaired physical capability [29], and are less likely to achieve the minimal amount of physical activity recommended by current guidelines that generally focus on MVPA or physical activities at higher intensities [2, 5, 30]. For this population, LPA may represent a desirable alternative. Together with the evidence that LPA could help to reduce the risk of all-cause and cancer death in older adults [26, 31] and given that increased LPA is associated with

Table 1. Characteristics of the included studies

Study source	Study name	Sample size		Age[a], years	BMI[a], kg/m^2	Follow-up[a]	LPA definition	Adjusted covariables
		Total	Events					
LPA and risk of cardiovascular disease								
Ballin et al. 2020 [11]	HAI	3343	74	70.5	26.4	2.7	Actigraph GT3X+; 100–1951 CPM	Sex, accelerometer wear time, smoking status, marital status, level of education, disposable income, myocardial infarction, stroke, angina pectoris, antihypertensives, anticoagulants, statins, systolic blood pressure, visceral adipose tissue, fasting blood glucose, low-density lipoprotein cholesterol
Jefferis et al. 2019 [12]	BRHS	1181	122	78.4	27.1	4.9[b]	Actigraph GT3X+; 100–1040 CPM	Age, region of residence, season of wear, accelerometer wear time, social class, alcohol use, smoking, sleep time, living alone, BMI, and mobility disability
LaCroix et al. 2019 [13]	OPACH	5861	570	78.5	28.2	3.5	ActiGraph GT3X+; 19–518 counts/ /15 s	Age, race/ethnicity, highest education, current smoking, alcohol consumption, physical functioning, comorbidity, and self-rated health, BMI, systolic blood pressure, high-sensitivity C-reactive protein, total cholesterol, and high-density lipoprotein cholesterol
LPA and risk of cardiovascular mortality								
Ensrud et al. 2014 [14]	MrOS	2918	138	79.0	26.9[c]	4.5	SenseWear Pro Armband; 1.51–2.99 MET	Age, race, site, season, education, marital status, health status, smoking, comorbidity burden, depressive symptoms, cognitive function, number of instrumental activities of daily living impairments, and percentage of body fat
LaMonte et al. 2018[d] [15]	OPACH	6382	154	78.6	28.1	3.1	ActiGraph GT3X+; 19–518 counts/ /15 s	Awake accelerometer wear time, age, race and ethnicity, education, current smoking, alcohol intake in past 3 months, age at menopause, self-rated general health, and number of comorbid conditions

[a]All data were the means or the averages from different sub-categories; [b]The mean value was imputed using the median datum; [c]Data were imputed from the study by Orwoll et al. [40]; [d]This study reported results on low- and high-LPA, which were later combined into one dataset using a fixed-effects model

Abbreviations: BMI, body mass index; BRHS, the British Regional Heart Study; CPM, counts per minute; HAI, Healthy Ageing Initiative; LPA, light-intensity physical activity; MET, metabolic equivalent; MrOS, the Osteoporotic Fractures in Men Study; n.a., not applicable; OPACH, the Objective Physical Activity and Cardiovascular Health; VM, vector magnitude

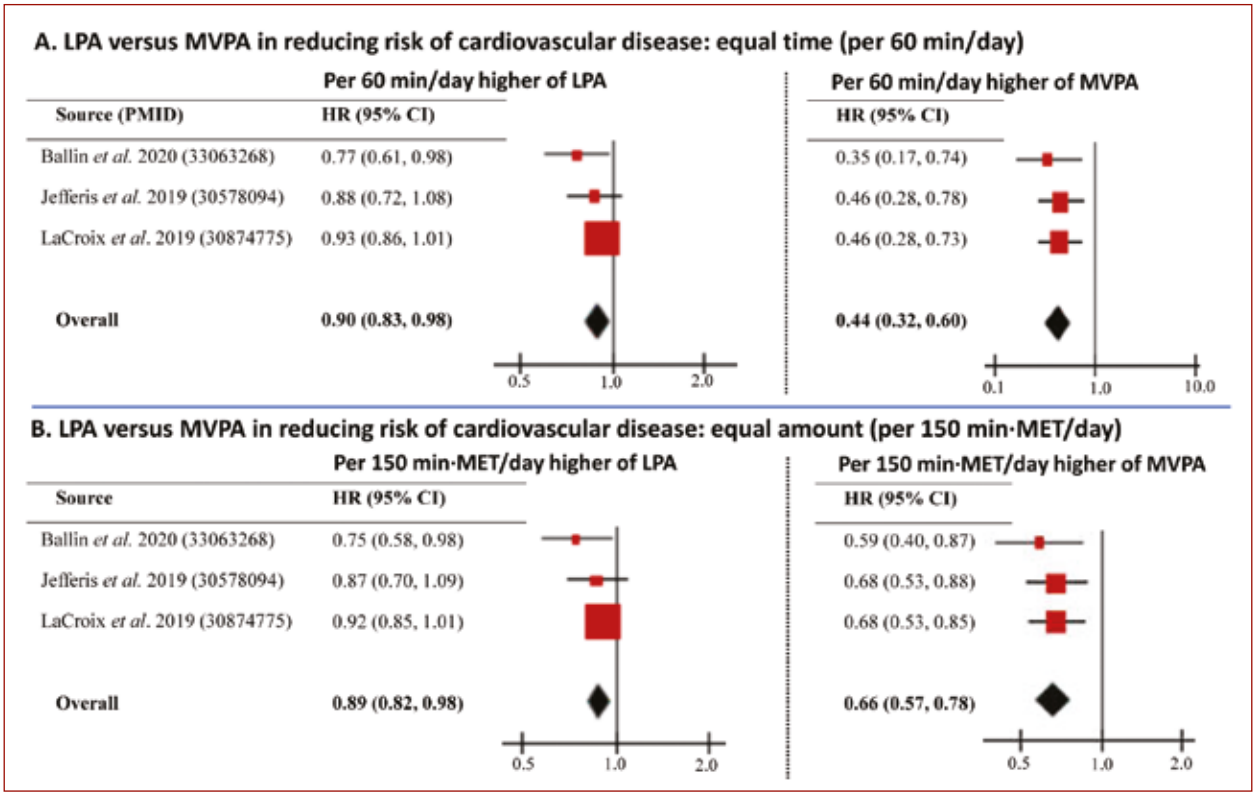

Figure 2. LPA vs. MVPA and the risk of cardiovascular disease in older adults; **A.** Per 60 min/day higher of LPA *vs.* that of MVPA in reducing the risk of cardiovascular disease; **B.** Per 150·METs/day higher of LPA *vs.* that of MVPA in reducing the risk of cardiovascular disease

Abbreviations: CI, confidence interval; HR, hazard ratio; LPA, light-intensity physical activity; METs, metabolic equivalents; MVPA, moderate-to-vigorous physical activity

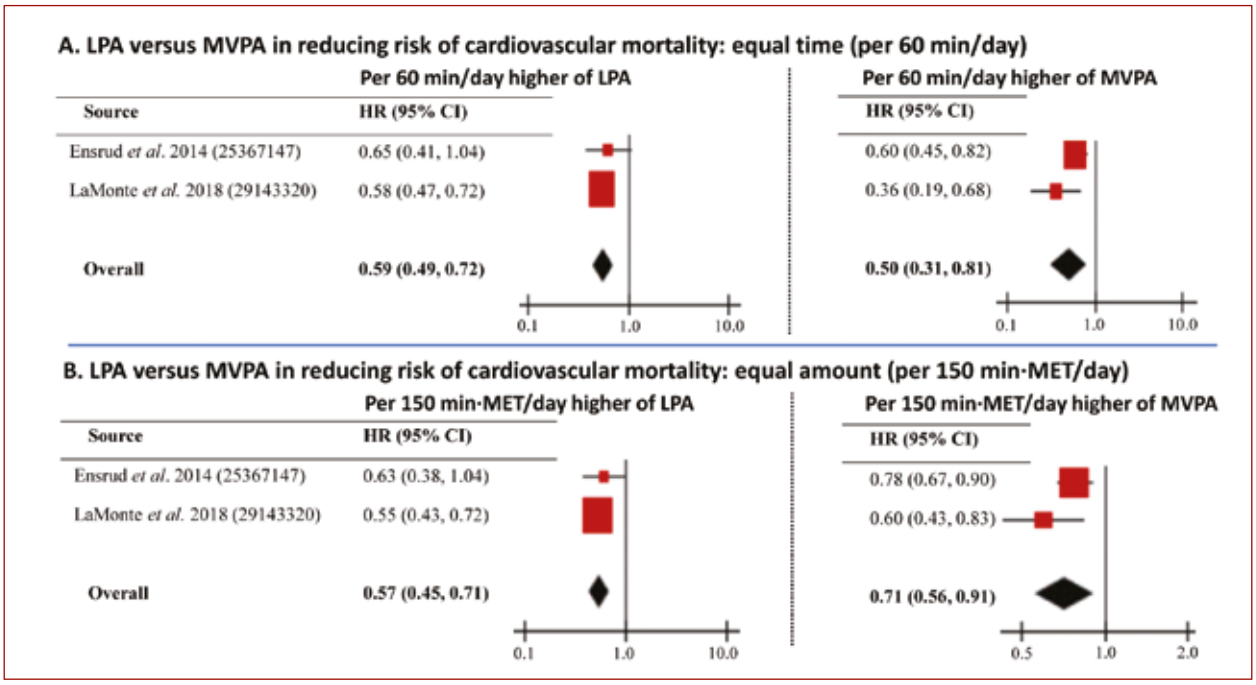

Figure 3. LPA versus MVPA and the risk of cardiovascular death in older adults; **A.** Per 60 min/day higher of LPA *vs*. that of MVPA in reducing the risk of cardiovascular death; **B.** Per 150·METs/day higher of LPA *vs*. that of MVPA in reducing the risk of cardiovascular death

Abbreviations: see Figure 2

improved cognitive functioning [32] and a better profile of cardiometabolic control [33], our findings suggest that LPA should be routinely recommended for older adults, and advice on how to promote LPA (e.g., using pedometers to increase daily physical activity [34]) should be integrated into clinical practice.

Our study found that LPA was inferior to MVPA in reducing the risk of cardiovascular disease in older adults, which is consistent with the findings by Saint-Maurice et al. [18] that the intensity of physical activity might matter more than its amount in reducing the risk of all-cause death. However, in terms of cardiovascular death, LPA was comparable to MVPA, either in equal time or equal amount scale. These results, taken together, indicate that emphasis on the intensity of physical activity might be not a must, at least for older adults; it rather depends on the expectation of health outcomes [35, 36]. For example, high-intensity interval exercise might be superior to MVPA to improve cardiorespiratory fitness [37, 38].

Our study suggested that there was a linear and inverse dose-response association between LPA and the risk of cardiovascular disease or death in older adults, while we could not obtain clear evidence for the target of the minimal amount of LPA necessary for health promotion. Yet based on the categorical data analysis from the study by Jefferis et al. [12], it appears likely that about 210 min/day of LPA, on average, might be sufficient to lower the risk of cardiovascular disease significantly in older men. However, another study with a much larger sample size conducted exclusively on women suggested that an average of 300 min/day of LPA might be required [13]. Nevertheless, more prospective cohort studies on this topic are still warranted.

Strengths and limitations

The strengths of our meta-analysis include a strict selection criterion limiting the study population to only older adults, the objective measurement of LPA by accelerometers, the inclusion of only prospective cohort studies, as well as the enhanced statistical power. However, several limitations in our meta-analysis should be noted. First, the differences in the definition of LPA and the relatively short duration of follow-up (<5 years) may weaken the robustness of our findings. Moreover, using aggregated data for LPA rather than the individual participant data may have caused some bias in data analysis. Second, we cannot prove the causality between LPA and the risk of cardiovascular disease and death in older adults. Third, the number of included studies was small. Although their data aggregation provided sufficient ability to obtain clinically meaningful outcomes, such findings are still required to be validated by future prospective studies. Fourth, the inclusion of only English-written studies may have led to an increased risk of selection bias. Finally, sedentary behavior has been recognized as an independent risk factor for cardiovascular disease or death [39], but none of the included studies controlled for this factor, which may influence the association of LPA with cardiovascular disease or death.

CONCLUSIONS

In conclusion, higher LPA was associated with a lower risk of cardiovascular disease and death, and its benefit in reduc-

ing the risk of cardiovascular death might be not inferior to MVPA in older adults. Recommendations of LPA for older adults should, therefore, be an important consideration in health guidelines.

Article information

Conflict of interest: None declared.

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