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ORIGINAL INVESTIGATIONS

Relationship of Daily Step Counts to All-Cause Mortality and Cardiovascular Events

Niels A. Stens, MSc,[a,b] Esmée A. Bakker, PhD,[a,c] Asier Mañas, PhD,[d,e,f,g] Laurien M. Buffart, PhD,[a] Francisco B. Ortega, PhD,[c,h,i] Duck-chul Lee, PhD,[j] Paul D. Thompson, MD,[k] Dick H.J. Thijssen, PhD,[a,l] Thijs M.H. Eijsvogels, PhD[a]

ABSTRACT

BACKGROUND The minimal and optimal daily step counts for health improvements remain unclear.

OBJECTIVES A meta-analysis was performed to quantify dose-response associations of objectively measured step count metrics in the general population.

METHODS Electronic databases were searched from inception to October 2022. Primary outcomes included all-cause mortality and incident cardiovascular disease (CVD). Study results were analyzed using generalized least squares and random-effects models.

RESULTS In total, 111,309 individuals from 12 studies were included. Significant risk reductions were observed at 2,517 steps/d for all-cause mortality (adjusted HR [aHR]: 0.92; 95% CI: 0.84-0.999) and 2,735 steps/d for incident CVD (aHR: 0.89; 95% CI: 0.79-0.999) compared with 2,000 steps/d (reference). Additional steps resulted in nonlinear risk reductions of all-cause mortality and incident CVD with an optimal dose at 8,763 (aHR: 0.40; 95% CI: 0.38-0.43) and 7,126 steps/d (aHR: 0.49; 95% CI: 0.45-0.55), respectively. Increments from a low to an intermediate or a high cadence were independently associated with risk reductions of all-cause mortality. Sex did not influence the dose-response associations, but after stratification for assessment device and wear location, pronounced risk reductions were observed for hip-worn accelerometers compared with pedometers and wrist-worn accelerometers.

CONCLUSIONS As few as about 2,600 and about 2,800 steps/d yield significant mortality and CVD benefits, with progressive risk reductions up to about 8,800 and about 7,200 steps/d, respectively. Additional mortality benefits were found at a moderate to high vs a low step cadence. These findings can extend contemporary physical activity prescriptions given the easy-to-understand concept of step count. (Dose-Response Relationship Between Daily Step Count and Health Outcomes: A Systematic Review and Meta-Analyses; CRD42021244747) (J Am Coll Cardiol 2023;82:1483-1494) © 2023 by the American College of Cardiology Foundation.

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From the [a]Department of Medical BioSciences, Radboud University Medical Center, Nijmegen, the Netherlands; [b]Department of Cardiology, Radboud University Medical Center, Nijmegen, the Netherlands; [c]Department of Physical Education and Sports, Faculty of Sports Science, Sport and Health University Research Institute, University of Granada, Granada, Spain; [d]GENUD Toledo Research Group, Faculty of Sports Sciences, Universidad de Castilla-La Mancha, Toledo, Spain; [e]CIBER de Fragilidad y Envejecimiento Saludable, CIBERFES, Instituto de Salud Carlos III, Madrid, Spain; [f]Center UCM-ISCIII for Human Evolution and Behavior, Madrid, Spain; [g]Didactics of Languages, Arts and Physical Education Department, Faculty of Education, Complutense University of Madrid, Madrid, Spain; [h]CIBERobn Physiopathology of Obesity and Nutrition, Granada, Spain; [i]Faculty of Sport and Health Sciences University of Jyväskylä, Jyväskylä, Finland; [j]Department of Kinesiology, Iowa State University, Ames, Iowa, USA; [k]Division of Cardiology, Hartford Hospital, Hartford, Connecticut, USA; and the [l]Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, United Kingdom.

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ABBREVIATIONS AND ACRONYMS

aHR = fully adjusted HR

CVD = cardiovascular disease

Regular physical activity reduces the risk for cardiovascular diseases (CVDs) and all-cause mortality in the general population.[1,2] Walking is an accessible type of physical activity that can be easily and accurately measured via commercially available smart phones or smart watches,[3] pedometers,[4] and accelerometers.[5,6] Daily step count represents an easy-to-use metric for the general population and may therefore have the potential to improve physical activity adherence and subsequent clinical outcomes.[7] Indeed, studies have shown that performing an additional 1,000 daily steps is associated with a 12% to 15% reduced risk for all-cause mortality[8,9] and lower odds for frailty.[10] Despite the potential of walking to improve health, the 2020 World Health Organization guidelines on physical activity and sedentary behavior do not include step count thresholds.[11] Several meta-analyses have qualitatively examined the dose-response association of daily step count,[8,9,12-15] but objective data extraction to identify minimal and optimal step-count doses have not yet been fully established. To enable the integration of evidence-based thresholds in future physical activity guidelines, the role of potential effect modifiers such as walking intensity (ie, step cadence[16]) should also be delineated, as previous studies reported mixed results.[17-19] Therefore, this systematic review and meta-analysis examines the dose-response association of objectively measured step count metrics with all-cause mortality and incident CVD in the general population. In addition, the moderating effects of: 1) sex; 2) step cadence; and 3) device and wear location of the step count assessment were explored.

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METHODS

This systematic review was performed according to the Meta-Analysis of Observational Studies in Epidemiology checklist[20] and registered in the PROSPERO database (CRD42021244747).

INFORMATION SOURCES AND SEARCH STRATEGY. A systematic literature search was performed in PubMed and EMBASE (Ovid), from inception to October 2022, using the search terms "daily step count," "step intensity," "objective step-measuring methods," "mortality," and "incident CVD" alone and in combination (Supplemental Table 1).

ELIGIBILITY CRITERIA. Studies were included if they: 1) quantified daily step count using objective step-counting methods (ie, accelerometry and pedometers); 2) examined the associations between step count and all-cause mortality or incident fatal or nonfatal CVD, including ischemic or coronary heart disease, stroke, and/or heart failure; 3) had a prospective cohort study design; 4) were peer reviewed, published in English, and accessible online; and 5) included adults aged ≥18 years without CVD at baseline. Studies addressing congenital heart disease were excluded.

DATA EXTRACTION AND QUALITY ASSESSMENT. Studies were selected by 2 independent researchers (N.A.S., E.A.B.). Potential papers were manually screened using titles and abstracts. Full-text publications were retrieved and reviewed. Both researchers discussed the results to reach consensus. Reference lists of relevant studies and systematic reviews were checked to ensure that no relevant studies were missing. Extracted descriptive data included the study's primary outcome, cohort name, covariates included in analysis, sample size, age, sex, number of events, body mass index, baseline step count, monitoring period, wear time, assessment device, wear location, follow-up duration, and shape of the dose-response curve. Investigators were contacted via e-mail in case insufficient data were reported.

Two researchers (N.A.S., E.A.B.) independently scored the risk for bias among the included studies using the Newcastle-Ottawa Scale.[21] In case of disagreement, consensus was reached by consulting a third researcher (T.M.H.E.). Studies were scored for selection, comparability, and outcomes using a 0- to 9-point score, where 1 to 3, 4 to 6, and 7 to 9 points reflect high, intermediate, and low risk for bias, respectively.

DATA SYNTHESIS AND ANALYSIS. Categorical and continuous dose-response associations between step count and clinical outcomes were tested. In addition, we explored the moderator effects of sex, step cadence, assessment device, and wear location.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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CATEGORICAL DOSE-RESPONSE ANALYSIS. Categorical dose-response analyses were performed for step count and cadence. Peak cadence represents the maximal number of steps performed during any specified period of time. Peak 30-minute cadence was included in our analyses, as this parameter was most frequently reported. We used a previously published approach[22,23] to pool study data and generate 3 categories for step count and cadence each (ie, low, intermediate, and high) (Supplemental Methods). Fully adjusted HRs (aHRs) were used to control for confounding variables. Transformation of aHRs and 95% CIs by the natural logarithm was performed to allow accurate estimation of the 95% CI for the pooled estimate. In essence, we compared the high and intermediate categories with the low category using random effects, as previously described.[24] Additional analyses were performed to examine: 1) the moderator effect of device type and wear location (ie, pedometer, hip-worn accelerometer, and wrist-worn accelerometer); and 2) the interplay between step cadence and step count. Heterogeneity was assessed using the I^2 and τ^2 statistics, with I^2 >50% indicating significant heterogeneity. Publication bias was explored using funnel plots and Egger tests.

CONTINUOUS DOSE-RESPONSE ANALYSIS. aHRs and 95% CIs per 500-step increment (range: 1,500-16,000 steps/d) were extracted from published dose-response curves using a graphical software program (WebPlotDigitizer version 4.5, Automeris).[25,26] Continuous dose-response associations between daily step count and all-cause mortality or incident CVD were based on a generalized least squares regression model using the maximum likelihood method. Nonlinearity was assessed by modeling step count using a restricted cubic spline. We tested 3 knots (at 5%, 50%, and 95% of step-count distribution),[27] 4 knots (at 5%, 35%, 65%, and 95%), and 5 knots (at 5%, 27.5%, 50%, 72.5%, and 95%), and subsequently compared the Akaike information criterion to identify the best fitting model. Linearity was tested using the Wald test. The reference level of the pooled dose-response curves was set at 2,000 steps/d, which was performed by subtracting the natural log-transformed aHR corresponding to 2,000 steps/d from the natural log-transformed aHRs of the full range of step counts. The dose at which minimal risk reductions were observed was set at the first step count, where the lower and upper bounds of the 95% CI were both <1. The optimal step-count dose was defined as the maximal risk reduction at the least effort (steps per day), reflecting the lowest step count at which the lower bound of the 95% CI exceeded the upper bound of the 95% CI of the lowest aHR (ie, overlap of CIs). We repeated these analyses using incremental reference categories (+1,000 steps/d) to compose a heatmap of the dose-response association between 2,000 and 16,000 steps/d. Dose-response models were truncated at 16,000 steps/d because of a paucity of data above this value. To explore effect modification, we additionally investigated the role of sex and accelerometry wear location. To test the robustness of our results, we performed a sensitivity analysis including only high-quality studies (Newcastle-Ottawa Scale score ≥7).

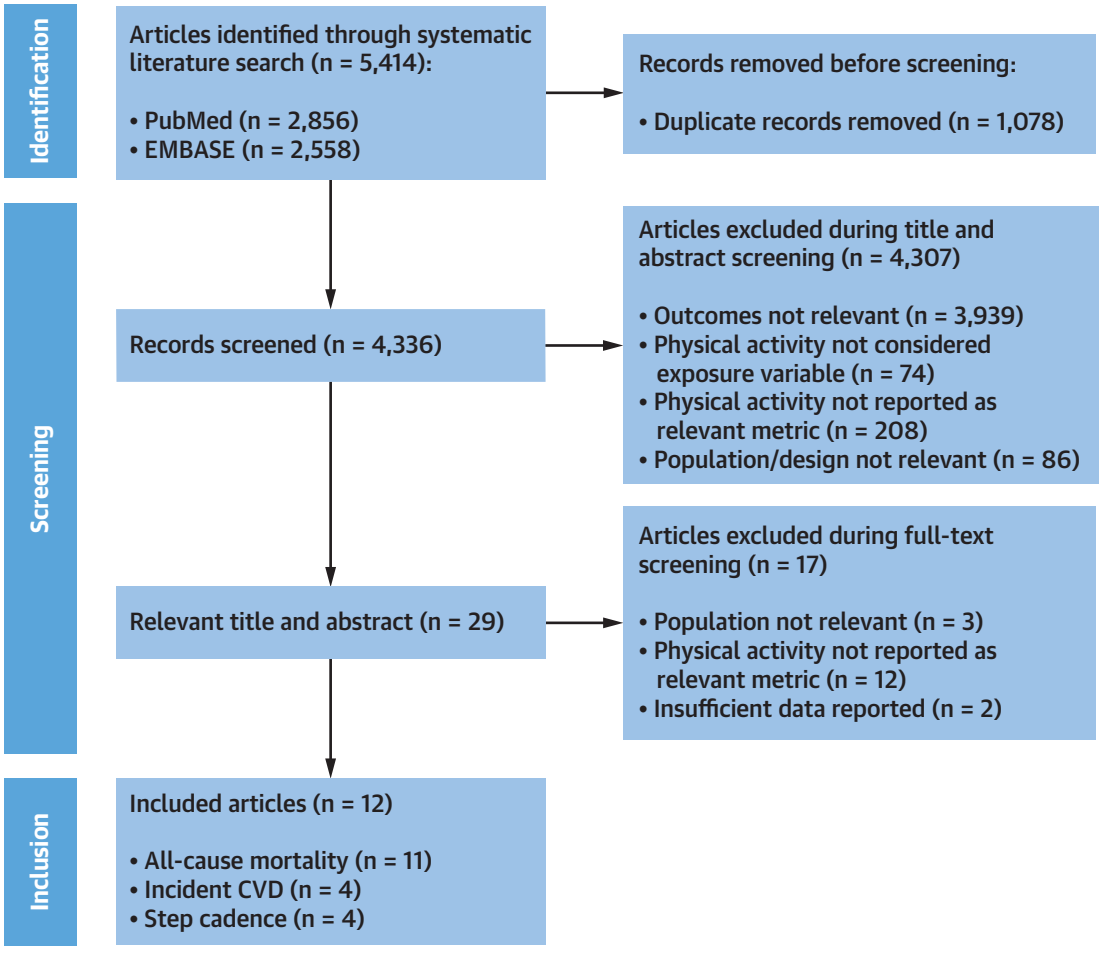
All analyses were performed in R version 4.02 (R Foundation for Statistical Computing) using meta version 5.1-1[28] and rms version 6.2-0.[29] A 2-tailed P value <0.05 indicated statistical significance. Baseline study characteristics were weighted for sample size to better reflect the characteristics of the overall population. Data are presented as mean ± SD, median (IQR), or frequency (proportion).

RESULTS

STUDY SELECTION. The systematic search identified 5,414 potential studies: 2,856 from PubMed and 2,558 from EMBASE (**Figure 1**). A total of 1,078 were duplicates, and 4,307 papers were excluded on the basis of title and abstract, leaving 29 papers that were screened for eligibility. Fifteen papers did not meet the inclusion criteria after reading the full text, and 2 papers[30,31] were excluded because of insufficient data, leaving 12 studies for inclusion. One study[32] shared unpublished data on the association between daily step count and cardiac hospitalizations. In total, 11 studies assessed the association between step count and all-cause mortality (n = 111,309),[17-19,32-39] 4 studies assessed step count and incident CVD (n = 85,261),[19,32,39,40] and 4 assessed step cadence and all-cause mortality (n = 102,191).[17-19,39]

STUDY AND POPULATION CHARACTERISTICS. The analytical cohort (Supplemental Table 2) objectively measured step count data from 111,309 individuals (60.8% women, mean age 62.5 ± 5.3 years, mean body mass index 27.0 ± 1.3 kg/m^2). The mean daily step count was 7,069 ± 904 steps/d. Of the 12 included studies, 1 study included only women,[17] and 2 included only men.[33,40] Step count was quantified using pedometers (n = 3)[35,37,38] or hip-worn (n = 8)[17-19,32-34,36,40] or wrist-worn (n = 1)[39] accelerometers. All studies measured step count for 7 days, except for 1 cohort that measured for 2 days.[38] Most studies corrected for age (n = 10), body mass index (n = 10), sex (n = 10), smoking status (n = 10), alcohol status (n = 9), education level (n = 7), and relevant comorbidities (n = 8)

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses Flowchart of the Review Process of Potential Papers



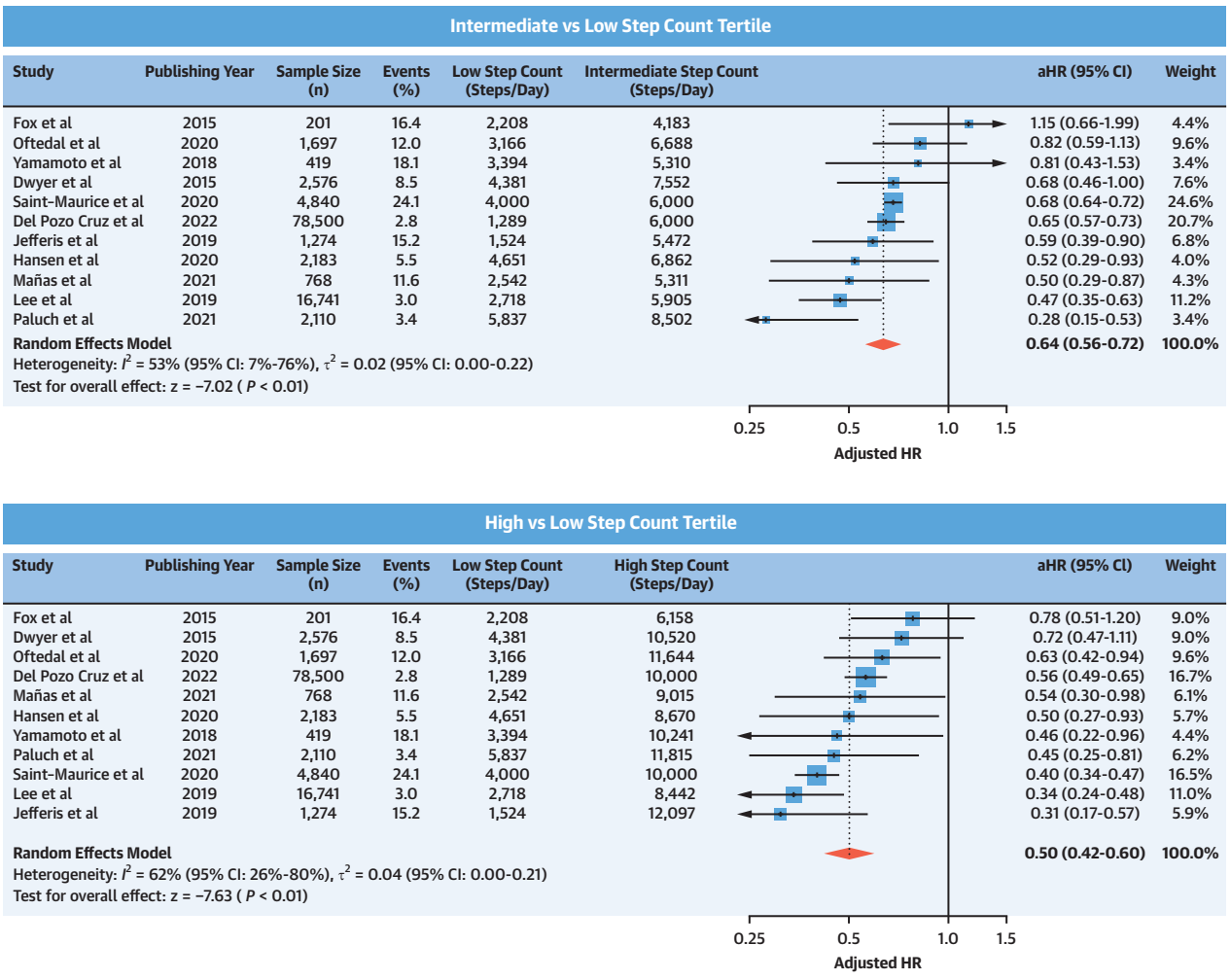
Potential papers were screened using titles and abstracts. Full texts were retrieved and reviewed. The systematic search identified 5,414 potential studies, of which 1,078 were duplicates, and 4,307 were excluded on the basis of title and abstract. Of the remaining 29 papers that were screened for eligibility, 15 did not meet the inclusion criteria after reading the full text, and 2 were excluded because of insufficient data, leaving 12 studies for inclusion. In total, 11 studies assessed the association between step count and all-cause mortality (n = 111,309), 4 studies assessed step count and incident cardiovascular disease (CVD) (n = 85,261), and 4 assessed step cadence and all-cause mortality (n = 102,191).

within their fully adjusted models. Most studies used national death registries[17-19,32-35,38-40] and death certificates[17] to assess endpoints.

QUALITY ASSESSMENT AND PUBLICATION BIAS. All studies had a low risk for bias (Newcastle-Ottawa Scale score ≥7), except for one[37] that had an intermediate risk for bias (Newcastle-Ottawa Scale score = 6) (Supplemental Table 3). Assessment of publication bias for the association between daily step count and all-cause mortality showed a symmetrical pattern, suggesting minimal publication bias (Supplemental Figure 1).

CATEGORICAL DOSE-RESPONSE ASSOCIATION BETWEEN DAILY STEP COUNT AND CLINICAL OUTCOMES. Among 111,309 individuals, 4,854 (4.4%) died during a median follow-up period of 77.8 months (IQR: 71.6-82.9 months). Intermediate step counts (median 6,000 steps/d [IQR: 5,392-6,775 steps/d]) were associated with a significantly lower mortality risk (aHR: 0.64; 95% CI: 0.56-0.72) (**Figure 2**) compared with the lower tertile (median 3,166 steps/d [IQR: 2,375-4,191 steps/d]). The risk reduction for the association with all-cause mortality was largest (aHR: 0.50; 95% CI: 0.42-0.60) (**Figure 2**) in individuals in

FIGURE 2 **Association Between Daily Step Count Tertiles and All-Cause Mortality**



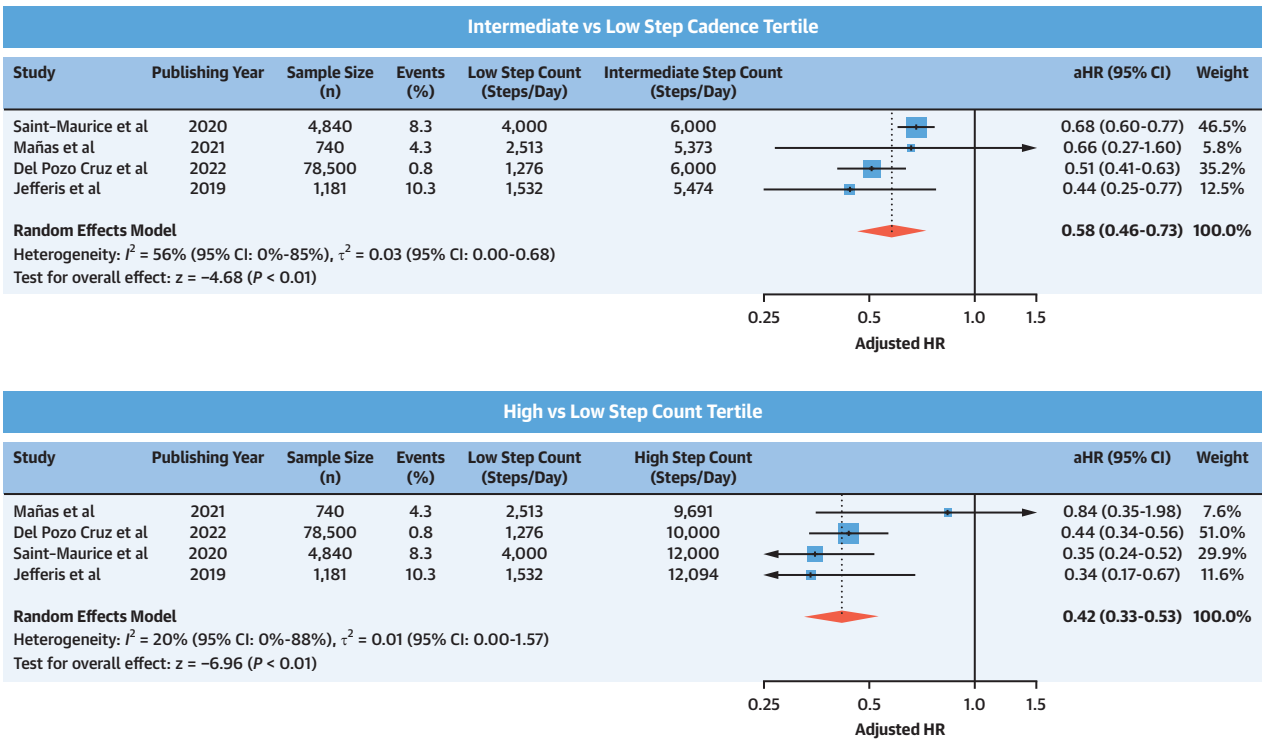
Individuals in the intermediate (median 6,000 steps/d [IQR: 5,392-6,775 steps/d]) and high (median 10,000 steps/d [IQR: 8,843-11,082 steps/d]) step count tertiles had a significantly lower mortality risk (36% and 50%, respectively) compared with the low step count tertile (median 3,166 steps/d [IQR: 2,375-4,191 steps/d]). For each study, **black vertical** and **horizontal lines** represent the effect estimate and 95% CI. Study weights were obtained using a random-effects analysis and are presented as **blue squares** and percentages. The **red diamond** represents the pooled estimate and its 95% CI. The low, intermediate, and high step counts reflect the average step count of the subjects in the respective group. aHR = adjusted HR.

the highest tertile (median 10,000 steps/d [IQR: 8,843-11,082 steps/d]).

A total of 1,224 individuals (1.4%) developed CVD events during 72.9 months (IQR: 66.4-80.4 months) of follow-up. The intermediate (median 5,737 steps/d [IQR: 5,449-6,000 steps/d]) and high step count (median 11,000 steps/d [IQR: 9,923-12,024 steps/d]) categories were associated with a lower risk for CVD (aHRs: 0.58 [95% CI: 0.46-0.73] and 0.42 [95% CI: 0.33-0.53], respectively) compared with the low step count category (median 2,022 steps/d [IQR: 1,468-2,885 steps/d]) (**Figure 3**).

CONTINUOUS DOSE-RESPONSE ASSOCIATION BETWEEN DAILY STEP COUNT AND CLINICAL OUTCOMES. The continuous dose-response analyses revealed nonlinear trends (P values for nonlinearity <0.001) for the associations between step count vs all-cause mortality and incident CVD (**Central Illustration**, Supplemental Figure 2). Risk reductions became statistically significant for the associations with all-cause mortality and CVD at 2,517 steps/d (aHR: 0.92; 95% CI: 0.84-0.999) and 2,735 steps/d (aHR: 0.89; 95% CI: 0.79-0.999), respectively. The minimal effective step count for all-cause mortality and CVD was 479

FIGURE 3 Association Between Daily Step Count Tertiles and Incident Cardiovascular Disease



Individuals in the intermediate (median 5,737 steps/d [IQR: 5,449-6,000 steps/d]) and high (median 11,000 steps/d [IQR: 9,923-12,024 steps/d]) step count tertiles had a lower risk for incident cardiovascular disease (42% and 58%, respectively) compared with the low step count tertile (median 2,022 steps/d [IQR: 1,468-2,885 steps/d]). For each study, **black vertical** and **horizontal lines** represent the effect estimate and 95% CI. Study weights were obtained using a random-effects analysis and are presented as **blue squares** and percentages. The **red diamond** represents the pooled estimate and its 95% CI. The low, intermediate, and high step counts reflect the average step count of the subjects in the respective group. aHR = adjusted HR.

steps/d (IQR: 399-644 steps/d) and 735 steps/d (IQR: 632-1,081 steps/d) above the reference category for other cutoff points (Supplemental Table 4). Further increases in step count were associated with decreased mortality and CVD risk until 8,763 steps/d (aHR: 0.40; 95% CI: 0.38-0.43) and 7,126 steps/d (aHR: 0.49; 95% CI: 0.45-0.55), after which additional reductions in mortality and incident CVD risk were not statistically significant (16,000 vs 2,000 steps/d: aHRs: 0.35 [95% CI: 0.30-0.40] and 0.42 [95% CI: 0.33-0.53], respectively) (**Central Illustration**). Changes in risk estimates following increases or decreases of 1,000 steps/d were strongly dependent on baseline step count (**Figure 4**).

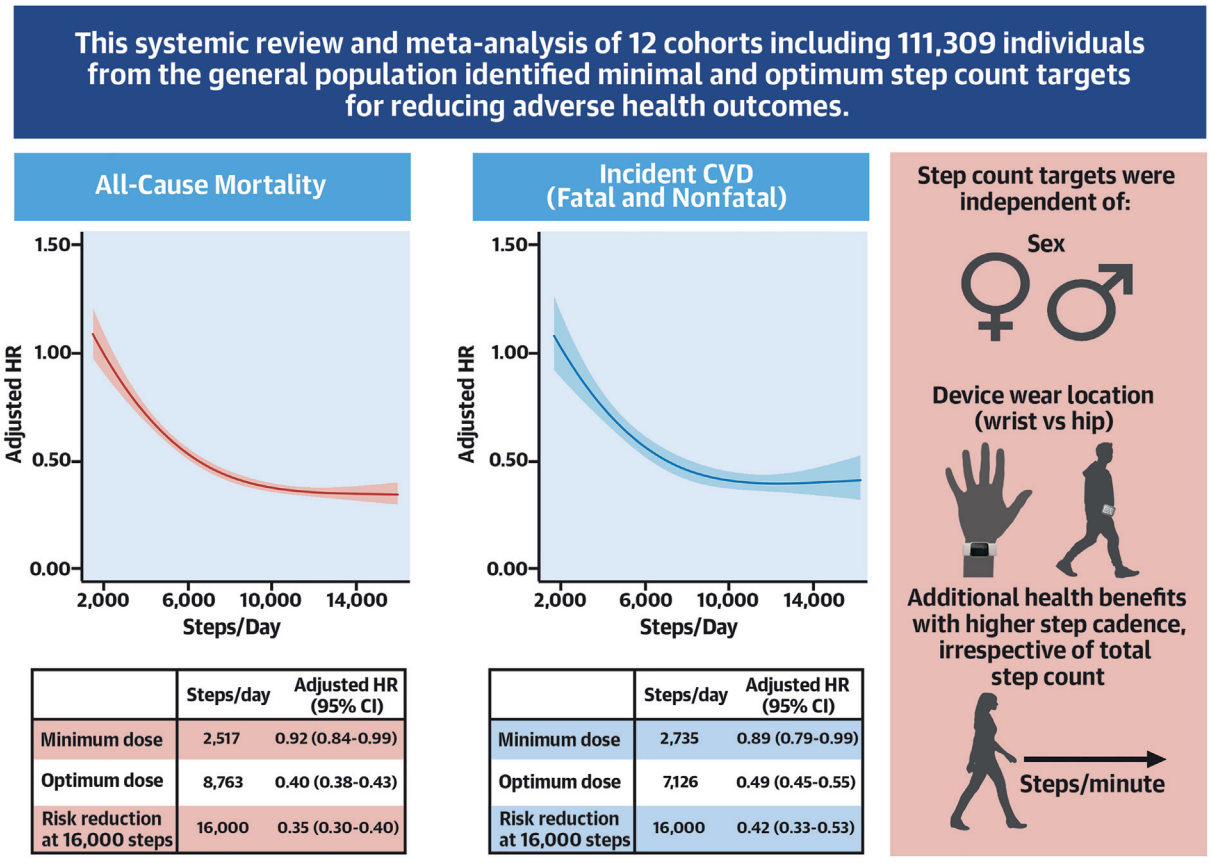
Comparable results were observed when only high-quality studies were examined (Supplemental Figure 3). Likewise, no important differences in risk reductions were observed between men and women (Supplemental Figures 4 to 6). Studies using hip-worn accelerometers were associated with more pronounced mortality risk reductions than studies using wrist-worn accelerometers (Supplemental Figures 7 to 9) and pedometers (Supplemental Figure 9).

STEP CADENCE AND MORTALITY. Intermediate (median 63 steps/min [IQR: 63-63 steps/min]) and high (median 88 steps/min [IQR: 88-88 steps/min]) cadences were associated with a lower mortality risk (aHRs: 0.67 [95% CI: 0.56-0.80] and 0.62 [95% CI: 0.40-0.97]) than a low cadence (median 29 steps/min [IQR: 28-30 steps/min]) (Supplemental Figure 10). Additional adjustment for step count attenuated these associations for intermediate cadence (aHR: 0.78; 95% CI: 0.65-0.93) and high cadence (aHR: 0.79; 95% CI: 0.67-0.94) (**Figure 5**).

DISCUSSION

Our meta-analyses quantified the dose-response association of objectively measured daily step count

CENTRAL ILLUSTRATION **Dose-Response Associations of Daily Step Count With Clinical Outcomes**



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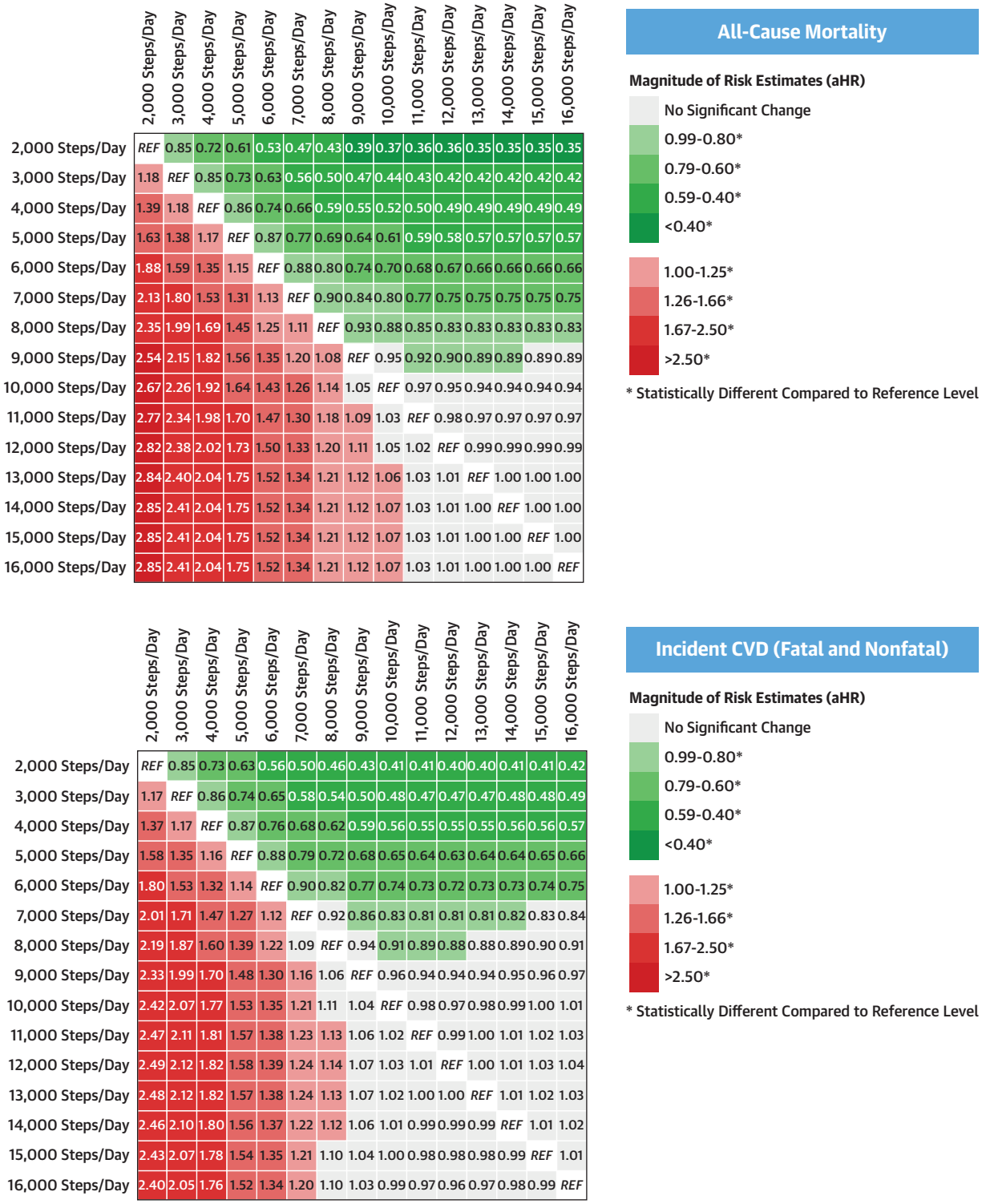
Dose-response curves for the association between daily step count vs all-cause mortality **(left)** and incidence of cardiovascular diseases (CVD) **(middle)**. Adjusted HRs (aHRs) from published dose-response curves were extracted and pooled using restricted cubic spline models. Compared with the reference level of 2,000 steps/d, the minimal dose to significantly reduce the risk for adverse outcomes was 2,517 steps/d for all-cause mortality and 2,735 steps/d for incident CVD. The optimal dose, defined as the maximal risk reduction at the least effort, was established at 8,763 steps/d for all-cause mortality and 7,126 steps/d for incident CVD. **Shaded areas** indicate the corresponding 95% CI.

metrics with all-cause mortality and incident CVD in the general population. Minimal doses of 2,517 and 2,735 steps/d were associated with an 8% reduction in all-cause mortality and an 11% reduction in CVD risk, respectively, compared with individuals accumulating 2,000 steps/d. The optimal doses were found at 8,763 steps/d for all-cause mortality (ie, 60% risk reduction) and 7,126 steps/d for incident CVD (ie, 51% risk reduction). Increasing from low to intermediate and high cadences was also associated with a decreased all-cause mortality risk (33% and 38% risk reductions, respectively), even after adjustment for daily step count (22% and 21% risk reductions, respectively). Risk reductions were greater for hip-worn accelerometers than for pedometers and wrist-worn accelerometers. There were no important differences in risk reductions with step count between men and women. Findings from this meta-analysis may optimize physical activity prescription in daily practice given the easy-to-understand concept of step count from a public health perspective.

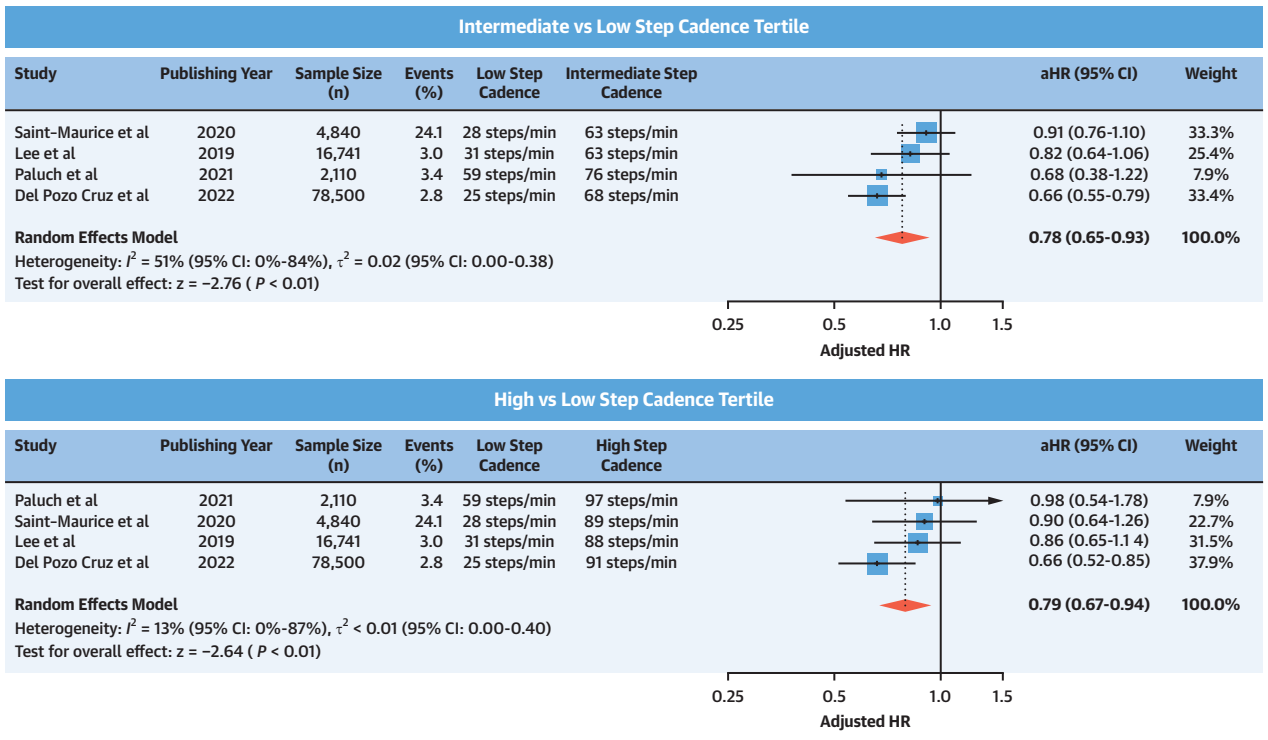
MINIMAL DOSE. We found that the minimal step-count dose needed to elicit significant health benefits was about 2,600 steps/d for all-cause mortality and about 2,800 steps/d for incident CVD in comparison with individuals who accumulated 2,000 steps/d. These findings highlight that behavior changes from physical inactivity to a lifestyle with

FIGURE 4 **Associations Between Different Step Count Volumes and Clinical Outcomes**



Heatmap visualization of the interplay between different step count volumes with all-cause mortality **(top)** and incident cardiovascular disease (CVD) risk **(bottom)**. Heatmaps should be interpreted row-wise. **Green** and **red values** indicate significant reductions and increases in risk, respectively, whereas **gray cells** indicate no significant difference compared with the reference level (REF). aHR = adjusted HR.

FIGURE 5 **Association Between Step Cadence Tertiles and All-Cause Mortality**



Forest plot highlighting the association between 30-minute peak cadence with all-cause mortality, adjusted for confounders and total step count. Individuals in the intermediate (median 66 steps/min [IQR: 63-67 steps/min]) and high (median 90 steps/min [IQR: 89-90 steps/min]) step cadence tertiles had a significantly lower mortality risk (22% and 21%, respectively) compared with the low step cadence tertile (median 25 steps/min [IQR: 25-25 steps/min]) after adjustment for total step count. For each study, **black vertical** and **horizontal lines** represent the effect estimate and 95% CI. Study weights were obtained using a random-effects analysis and are presented as **blue squares** and percentages. The **red diamond** represents the pooled estimate and its 95% CI. The low, intermediate, and high step cadences reflect the average step cadence of the subjects in the respective group. aHR = adjusted HR.

some physical activity may already produce risk reductions for all-cause mortality and incident CVD. It is important to highlight that such activity levels are feasible for the majority of the general population, including older adults and individuals with chronic diseases.[41] Increases of 1,000 steps/d were associated with additional health benefits (**Figure 4**), especially among those with a low number of baseline steps (Supplemental Table 4), highlighting that every step counts.

OPTIMAL DOSE. The optimal step-count dose was observed at about 8,800 and about 7,200 steps for all-cause mortality and incident CVD, respectively. Step counts beyond our optimal dose minimally improved health outcomes. This plateau suggests that most benefits were achieved at step counts <10,000 steps/d, which aligns with observations from recent other meta-analyses.[12,14] Although step volumes beyond this level were not associated with additional health benefits, there is no reason to discourage individuals from such behavior, as a highly physically active lifestyle may provide other benefits, such as joy, improved quality of life, and better sleep and mental health.[42,43]

STEPPING CADENCE. We found that intermediate and high cadences were associated with reduced risk for mortality and CVD morbidity, even after additional adjustment for daily steps. These findings underline that both volume (steps per day) and intensity (cadence, or steps per minute) are independently associated with health and that their risk reductions are additive. Cadence can be considered a proxy for fitness, as a higher cadence requires a greater oxygen consumption,[44,45] and higher fitness is associated with better event-free survival.[46,47] Similarly, a greater proportion of vigorous physical activity,

relative to the total amount of physical activity, is associated with a reduced mortality risk.[48-50] Hence, accruing step volumes at a higher step cadence may provide additional benefits compared with a low cadence.

DEVICE TYPE AND WEAR LOCATION. Reductions in mortality and CVD risks were larger for hip-worn accelerometers than pedometers and wrist-worn accelerometers. Hip-mounted devices are potentially more likely to accurately measure steps given their close proximity to locomotion acceleration. Alternatively, this observation may also relate to differences in cohort characteristics (ie, age, follow-up time, event rate), as we included only 1 study using a wrist-worn device. The lower risk estimate for pedometers may be due to underestimation of step count compared with accelerometers,[51] especially at slower cadences.[52] Nevertheless, the impact of these findings may be limited for future guidelines, as the minimal and optimal dose were not affected by the device type or wear location. Therefore, a uniform step count prescription may be adopted using different devices.

PRACTICAL IMPLICATIONS. This study revealed nonlinear dose-response curves between daily steps and health outcomes, with progressive risk reductions for mortality and CVD at a higher number of daily steps, independent of sex. The optimal dose of about 8,800 steps/d for mortality and about 7,200 for CVD may be used in future physical activity guidelines. Step count-based targets may enhance adherence to physical activity recommendations, as measurement devices are commercially available and provide reliable measurement of walking activity.[53] Physicians may stimulate individuals, even those who are moderately active, to increase their physical activity with at least 1,000 steps/d, as this target is feasible and can be achieved during about 10 minutes of walking activity.[54] As walking is accessible to the majority of the population, including those with chronic disease or with lower social economic status, and can be adjusted to a pace that matches the individual level of fitness, step count-based physical activity goals may become a promising public health tool.

STUDY STRENGTHS AND LIMITATIONS. The strengths include the large sample size (n = 111,309) and the ability to model continuous dose-response associations, while the risk for bias was low, with minimal evidence of publication bias. Nonetheless, several limitations should be considered. First, daily step counts were investigated only at baseline, but physical activity behavior may change over time and is influenced by various factors (eg, age, sex, socioeconomic status, disease state).[55,56] Repeated measures of daily step count could further strengthen the evidence.

Second, we were not able to quantify the effects of reverse causation and other relevant factors that influence daily step count, because of restrictions in available and published dose-response curves. Nonetheless, 10 of 12 studies concluded that their results were not likely to be affected by reverse causation when removing the first,[17,33,35,40] second[18,32,34,38,39] or third[37] follow-up years.

Third, only 4 studies investigated the additive effects of step cadence to total step count. Future studies are warranted to confirm our results. Fourth, observations from this study may not directly be extrapolated to chronically diseased, older, and low-income populations. Although the minimal and optimal step counts may represent relevant targets for these populations, the magnitude of risk reductions may be different, as distinct dose-response relationship between physical activity and health were previously presented for individuals with CVD vs healthy control subjects.[57]

CONCLUSIONS

Lower risk for all-cause mortality and incident CVD may already be experienced after about 2,600 and about 2,800 steps/d, respectively. Additional increments of 1,000 steps/d (about 10 minutes of walking) enhance risk reductions in a nonlinear fashion. Optimal health benefits were achieved at about 8,800 steps/d for all-cause mortality and about 7,200 steps/d for incident CVD. A higher cadence provides additional health benefits beyond total step volume. As health benefits of daily steps were similar between men and women and step count targets were independent of wear location and device, the integration of uniform daily step targets in future physical activity guidelines may be relevant from a public health perspective, as “every step counts.”

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ADDRESS FOR CORRESPONDENCE: Dr Thijs M.H. Eijsvogels, Department of Medical BioSciences (928), Radboud University Medical Center, PO Box 9101, 6500 HB Nijmegen, the Netherlands. E-mail: thijs.eijsvogels@radboudumc.nl. @ThijsEijsvogels.

PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: Using data from 111,309 individuals, minimal (~2,600 and ~2,800 steps/d) and optimal (~8,800 and ~7,200 steps/d) step counts were associated with lower rates of all-cause mortality and cardiovascular events, respectively, independent of sex, device type, or wearable location.

TRANSLATIONAL OUTLOOK: Further research is needed to determine how best to adjust step-count targets over time, integrate step-count recommendations with step cadence, and adjust recommendations on the basis of individual patient characteristics.

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KEY WORDS exercise, health outcomes, physical activity, population, public health, walking

APPENDIX For supplemental Methods as well as supplemental tables and figures, please see the online version of this paper.