Step Counter Use and Sedentary Time in Adults

A Meta-Analysis

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Abstract: Although step counters are increasingly being used in walking programmes to promote sedentary behavior changes in adults, their effectiveness remains unknown. The aim of this meta-analysis of randomized controlled trials (RCTs) was to assess the effectiveness of step counter use in reducing sedentary time among adults.

English-language RCTs from 3 databases were searched up to December 2014. Studies were included if they evaluated the effects of step counter use in adult populations and reported outcomes in sedentary time. Summary estimates (Cohen d with 95% confidence intervals [CIs]) were pooled using a random-effects model. Subgroup analyses and random-effects meta-regression analyses based on the characteristics of participants or interventions were conducted to explore their associations with sedentary time changes.

Fifteen RCTs with a total sample size of 3262 adults were included. Step counter use was associated with a small but significant overall effect in reducing sedentary time ($d = -0.20, 95\% CI = -0.33$ to $-0.07$), equating to a reduction in sedentary time of $\sim 23$ min/d compared with controls. Subgroup analyses showed that step counter use with a step goal was associated with significantly reduced sedentary time ($d = -0.32, 95\% CI = -0.53$ to $-0.11$), whereas without, it had only a trend. A greater reduction in sedentary time was observed among step counter users employing objective methods than those employing subjective methods for measurement ($P = 0.03$). Effects of covariates on sedentary time changes were generally unclear.

Step counter use is associated with reduced sedentary time among adults. Future studies are required to specify the step goal use and to employ objective as well as subjective methods for measuring both total and domain-specific sedentary time.

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Content 2, http://links.lww.com/MD/A390, which describes the registered protocol). Searches were restricted to peer-reviewed English-language research articles in the databases of PubMed, Web of Science, and the Cochrane Central Register of Controlled Trials from inception through December 12, 2014. Search strategies were built around 2 groups of text words or Medical Subject Headings terms related to step counters and sedentary time, along with entry terms associated with a sensitive search filter for RCTs (Table, Supplemental Digital Content 3, http://links.lww.com/MD/A390, which shows the search strategies).29 In addition, manual searches of reference lists from relevant publications, systematic reviews, or meta-analyses were conducted to supplement the electronic searches. Gray literature such as dissertations and unpublished data were not sought because it was impractical to identify them from all authors and institutions around the world.

**Study Selection**

The criteria for inclusion were defined based on the “PICOS” principle, that is, participants, interventions, comparisons, outcomes, and study design. Studies were included if they included adult populations (mean ages ≥18 years), used step counters (eg, pedometers, accelerometers) as the intervention for physical activity motivation (eg, walking more), compared with control groups that received usual care, were asked to maintain current lifestyle, or received interventions that had nothing to do with physical activity or sedentary behavior, reported change scores or postintervention values of sedentary time (eg, time spent being sedentary or sitting) assessed by subjective (eg, International Physical Activity Questionnaire [IPAQ]) or objective methods (eg, accelerometers), and were RCTs. To assess the long-term effect of step counter use in reducing sedentary time among adults, the length of step counter intervention was restricted to 8 weeks or longer—a time window that is widely used for evaluating the intervention effects on health outcomes or metabolic profiles.29,30

Studies were excluded if they included children or adolescents, used step counters only for measuring physical activity or sedentary time, or had step counters sealed in the intervention groups or unsealed in the control groups. Studies were also excluded if they enrolled adults requiring to be hospitalized (eg, inpatients), were posters or nonrandomized studies, or did not report outcomes in sedentary time including the case that such information could not be obtained from the corresponding authors.

**Data Extraction and Quality Assessment**

All retrieved citations together with the abstracts were downloaded to EndNote X5 (Thompson Reuters, San Francisco, CA) and duplicates were removed using “duplicate” function or by hand. Following initial title and/or abstract screen, full-text articles were retrieved for any studies deemed appropriate or of uncertainty about their eligibility. Data were extracted from studies that met all inclusion criteria using a standardized data collection form, which included characteristics of study participants (including population sources, number of participants, mean ages, and body mass index [BMI] at entry, sex [proportion of women], and baseline mean sedentary time [unit, min/d]); characteristics of study interventions (including description of the interventions [eg, step goal use, components on sedentary behavior changes, methods for sedentary time measurement] and length of interventions); characteristics of control groups; outcomes of interest (changes in sedentary time or postintervention values [unit, min/d]); details of study sources (including authors and date of publication). In addition, average baseline values and change scores of total walking steps (unit, steps/d) and physical activity (including light, moderate, vigorous, moderate-to-vigorous, and total physical activity [unit, min/d]) were also extracted.

The Cochrane risk of bias tool was used to assess the methodological quality within included RCTs.31 For each RCT, 6 domains were judged to be of high, low, or unclear risk for bias: sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, and selective outcome reporting. These 6 domains assess the level of risk regarding selection bias, performance bias, detection bias, attrition bias, and reporting bias.

Two independent authors (S.Q. and X.C.) conducted the literature selection, data extraction, and quality assessment in an unblinded manner. When disagreements occurred, consensus was achieved through discussion with a third author (U.S.).

**Data Synthesis and Analysis**

Change scores from baseline or postintervention values of sedentary time expressed as means with standard deviations from studies using intention-to-treat or per-protocol analyses were entered in the same meta-analysis.31 For studies that did not report means, they were imputed by using medians directly. For studies that did not report standard deviations, they were calculated from standard errors, 95% confidence intervals (CIs), interquartile ranges, or ranges.31,32 For studies that had 2-step counter intervention or control groups, these groups were combined into 1 group to create a single pairwise comparison and to overcome a unit-of-analysis error.31 Moreover, for studies that reported outcome variables at different time points within the intervention period, outcomes from the last time point were used for primary analyses.31

Outcome estimates expressed as Cohen \( d \) and 95% CIs were assessed using a random-effects model, which better accounts for between-study heterogeneity than a fixed-effects model.31 The reason for choosing Cohen \( d \) as the effect size rather than weighted mean differences was due to the different methods in measuring sedentary time (questionnaires versus instruments). Interpretation of the effect size was based on Cohen criteria, where \( d \leq 0.20 \) represents a small effect, 0.20 to 0.40 a medium effect, and \( d \geq 0.70 \) a large effect.33 Statistical heterogeneity was assessed using the Cochrane \( Q \) test (considered the \( Q \) test with a \( P < 0.10 \) as heterogeneous) and the \( I^2 \) index (considered an \( I^2 \) value \( \geq 50\% \) as heterogeneous).31

Subgroup analyses based on step goal use (with versus without) and components focused on sedentary behavior changes (with versus without) were performed to evaluate their influences on outcome estimates. Another subgroup analyses on the basis of subjective and objective methods were conducted to compare their sensitivities or accuracies in determining sedentary time. Univariate, weighted random-effects meta-regression analyses were carried out to assess whether the changes in outcome estimates could be mediated by the following factors: baseline mean age (logarithmic transformation), BMI, sedentary time and physical activity, sex, length of intervention, and physical activity changes. Sensitivity analyses by removing each individual study from the meta-analysis were conducted to determine whether any particular study would significantly change the outcome estimates. Publication bias was evaluated using the Begg test and the Egger test at the \( P < 0.10 \) level of
significance. If publication bias was detected, the trim-and-fill computation was used to assess the effect of publication bias on the interpretation of the outcome estimates. Unless otherwise specified, a $P < 0.05$ was considered significant. Statistical analyses were performed using STATA software (version 12.0; College Station, Texas, USA) and Review manager (version 5.2; the Nordic Cochrane Centre, Copenhagen, Denmark).

**RESULTS**

**Study Characteristics**

The literature search results and the study selection process are shown in Figure 1. In total, 1603 articles were identified, where 344 were from PubMed, 829 from Web of Science, 411 from the Cochrane Central Register of Controlled Trials, and 19 from identified systematic reviews or meta-analyses. After duplicate exclusion, title/abstract review, and full-text assessment, 15 studies met the inclusion criteria and were included in the final meta-analysis.

The characteristics of the included studies are summarized in Table 1. A total sample size of 3262 participants (1649 as intervention participants and 1613 as controls) was pooled from the 15 studies. Most of the included participants were overweight or obese, and physically inactive or sedentary. The length of step counter intervention varied from 8 to 48 weeks.

All studies reported data on sedentary time, with 8 of them using subjective methods (6 with IPAQ and 2 with other questionnaires) and 6 using objective methods (3 with accelerometer [details not provided], 2 with ActivPAL [PAL Technologies, Glasgow, Scotland], 1 with StepWatch [OrthoCare Innovations, Mountlake Terrace, WA]). Seven studies reported adherence to step counter use among participants who completed the intervention, with an average rate of 79%. Eight studies had dropout rates $< 20\%$, while they were higher than 20% among the other studies except one that did not report.

Three studies were from the United States, 9 from Europe, and 3 from Australia. The risk-of-bias assessment for each study is described in Supplemental Digital Content 4, http://links.lww.com/MD/A390. The largest risk of bias came from attrition bias, with 7 of the included studies using improper methods in dealing with incomplete outcome data. Because of the nature of step counter intervention, which requires unsealed step counters to promote physical activity and to reduce sedentary time, complete blinding of participants and personnel is impossible and unnecessary, and therefore, the risk of performance bias was judged to be low.
| Author, y | Population | Intervention and Control Description | Duration, wk | Step Goal | Elements on SB | ST Measurement |
|-----------|------------|--------------------------------------|--------------|-----------|---------------|---------------|
| Petersen et al,10 2012 | Inactive adults | Intervention: received a pedometer-based walking program including a pedometer, a book with a pedometer-based goal-setting program, and a logbook | 12 | Self-set goal | No | IPAQ |
| Kozey Keadle et al,11 2014 | Inactive overweight/obese adults | Intervention: received ST reduction strategies and pedometers for self-monitoring of behavior | 12 | Other goal | Yes | ActivPAL |
| Morgan et al,12 2013 | Overweight/obese men | Intervention: received Self-Help, Exercise and Diet programmes, which included the pedometer use aimed to increase exercise | 12 | Self-set goal | Yes | Sitting Questionnaire |
| Lane et al,13 2013 | Inactive women | Intervention: received tailored physical activity booklets including pedometers for physical activity promotion | 9 | Not stated | No | IPAQ |
| Aittasalo et al,14 2012 | Inactive employees | Intervention: received a pedometer-based intervention including emphasis on stairs use, walking leaflets, pedometers, logbooks, and monthly email messages | 24 | Self-set goal | No | IPAQ |
| Suboc et al,15 2014 | Sedentary older adults | Intervention: received a pedometer intervention with motivational messages and weekly physical activity counseling. | 12 | 10,000 steps/d | No | Accelerometer |
| Burke et al,16 2013 | Adults with insufficient activity | Intervention: received a home-based program supported by an exercise chart, calendar, bimonthly newsletters, resistance band, pedometer, phone calls, and emails | 24 | Not stated | No | IAPQ |
| Verweij et al,17 2012 | Employees with unhealthy lifestyle behaviors | Intervention: received guideline-based care including behavioral change counseling, goal-setting, and behavior monitoring on physical activity and nutrition by using a toolkit contained a pedometer and leaflets | 24 | Not stated | Yes | IPAQ |
| De Greef et al,18 2011 | Overweight/obese adults with type 2 diabetes | Intervention: received usual care with 10,000 steps/d | 24 | Yes | Accelerometer and IPAQ |
| Author, y | Population | Intervention and Control Description | Duration, wk | Step Goal | Elements on SB | ST Measurement |
|-----------|------------|--------------------------------------|--------------|-----------|----------------|----------------|
| Carr et al,19 2013 | Inactive adults | Intervention: received a portable pedal machine, a motivational website, and a pedometer with feedbacks, aiming to reduce ST | 12 | Other goal | Yes | StepWatch |
| Andrews et al,20 2011§ | Overweight/obese adults with type 2 diabetes | Intervention: received intensive diet intervention and were instructed to do brisk walking and walk more with pedometer use | 48 | Not stated | No | Accelerometer |
| De Greef et al,21 2010 | Adults with type 2 diabetes | Intervention: received a cognitive-behavioral program including a pedometer, instructions for increasing self-efficacy and setting goals | 12 | Self-set goal | Yes | Accelerometer |
| Baker et al,22 2008 | Adults with insufficient activity | Intervention: received a physical activity consultation and a pedometer-based walking program | 12 | Other goal | No | IPAQ |
| Mutrie et al,23 2012 | Adults with insufficient activity | Intervention: two 30-min physical activity consultations and a pedometer-based walking program | 12 | Self-set goal | No | ActivPAL |
| Gilson et al,24 2009jj | Employees with different activity levels | Intervention: received pedometers and were asked to increase step counts through brisk, route-based walking, or to take incidental walking and accumulate step counts | 10 | 10,000 steps/d | Yes | Questionnaire |

IPAQ = International Physical Activity Questionnaire, RCT = randomized controlled trial, SB = sedentary behavior, ST = sedentary time.

Duration means the length of step counter intervention.

§ It had 2 control groups: usual care and intensive diet intervention groups.

1 It had 2 intervention groups: ST reduction and exercise training plus ST reduction groups.

2 It had 2 intervention groups: pedometer only and pedometer plus website groups.

4 It had 2 control groups: usual care and intensive diet intervention groups.

11 It had 2 intervention groups: route and incidental walking groups.
Meta-Analysis of Step Counter Use and Sedentary Time

Fifteen studies involving a total of 3262 adults were pooled in this meta-analysis. Step counter use was associated with a small but significant overall reduction in sedentary time ($d = -0.20, 95\% \text{ CI } -0.33$ to $-0.11$; Figure 2), where the effect size was equaled to a reduction in sedentary time of $\sim 23\text{ min}/\text{d}$ compared with the controls. The Cochrane $Q$ test indicated substantial heterogeneity among study results ($P = 0.001$), with an $F$ value estimating that 62% of the variance is caused by between study differences.

Subgroup analyses showed that step counter use together with a step goal led to a significant reduction in sedentary time ($d = -0.32, 95\% \text{ CI } -0.53$ to $-0.11$), even though heterogeneity between studies remained high ($F = 68\%, P = 0.001$); whereas without, there was only a trend toward reduced sedentary time ($d = -0.09, 95\% \text{ CI } -0.21$ to $0.04; F = 38.7\%, P$ for heterogeneity $0.18$) (Table 2). The overall effect sizes did not differ significantly ($P = 0.42$) between step counter use with ($d = -0.29, 95\% \text{ CI } -0.54$ to $-0.04$) or without ($d = 0.17, 95\% \text{ CI } -0.33$ to $0.01$) interventions aiming to promote sedentary behavior changes (Table 2). Notably, studies using objective methods for sedentary time measurement showed a greater reduction in sedentary time compared with those using subjective methods ($d = -0.52, 95\% \text{ CI } -0.88$ to $-0.15$ vs $d = -0.09, 95\% \text{ CI } -0.19$ to $0.11, P = 0.03$ for between-group comparison), whereas heterogeneity of the latter subgroup was low ($I^2 = 24.5\%, P = 0.23$).

The random-effects meta-regression analyses showed that none of the following covariates were the potential predictor of changes in sedentary time: baseline age (β coefficient, $-0.055, P = 0.93$), baseline BMI ($-0.039, P = 0.33$), sex ($-0.15, P = 0.66$), length of intervention ($0.009, P = 0.26$), baseline sedentary time ($-0.00003, P = 0.91$), baseline walking steps ($0.00004, P = 0.79$), and changes in walking steps ($-0.0001, P = 0.69$). Besides, neither the baseline values nor change scores of light, moderate, vigorous, moderate to vigorous, or total physical activity were found to be associated with changes in sedentary time (Table 3). When studies were individually removed, the overall effect sizes remained largely unchanged. Statistical evidence of publication bias was found among these studies (Begg test, $P = 0.001$; Egger test, $P = 0.01$). However, the application of the trim and fill method did not identify any missing study (Figure, Supplemental Digital Content 5, http://links.lww.com/MD/A390, which shows the graph of the filled funnel plot) or change the overall effect size ($d = -0.20, 95\% \text{ CI } -0.33$ to $-0.07$).

**DISCUSSION**

This meta-analysis shows that among adults, step counter use was associated with a small but significant overall effect in reducing sedentary time compared with controls. It further shows that step goal setting was a key predictor of reduced sedentary time, whereas having interventions aiming to promote sedentary behavior changes seemed to be not. Furthermore, this study also shows that using objective methods (eg, accelerometers) for sedentary time measurement obtained a greater reduction in sedentary time compared with using subjective methods (eg, questionnaires), indicating that objective methods might have a higher sensitivity or accuracy than subjective methods in determining sedentary time.

Step counters are commonly used in walking programmes, and our results are partly in agreement with the findings from Prince et al,$^{23}$ who showed that physical activity interventions

![FIGURE 2. Forest plot examining the association between step counter use and sedentary time among adults. (A) The sample size represented the number of participants included in the per-protocol or intention-to-treat analyses. (B) Effect size was calculated using a random-effects model. (C) Data of sedentary time were imputed using the combined mean values of sedentary time on work and nonwork days. (D) Accelerometer-measured sedentary time was used in this meta-analysis. CI = confidence interval.](image-url)
were associated with a significant but small reduction in sedentary time among adults. However, the authors failed to specify the applied physical activity interventions. Among the characteristics of step counter interventions, having a step goal was found to be essential in reducing sedentary time, whereas the respective benefits of using different step goals in reducing sedentary time remain unclear. Interestingly, on the one hand, in studies where step counter users had a 10,000 steps/d goal, there was only an overall trend toward reduced sedentary time, which could also be seen in the individual studies. On the other hand, setting an alternative personalized step goal yielded significantly reduced sedentary time among step counter users, although the step goals varied substantially from each other. Therefore, to specify the goal use among step counter users is required in future studies.

It has been well documented that interventions with focus on reducing sedentary behaviors are associated with clinically meaningful reductions in sedentary time. This is reasonably in accordance with our findings that step counter use with interventions aiming to promote changes in sedentary behaviors was correlated with reduced sedentary time. However, it is worth noting that this recommendation might be unnecessary because a comparable reduction in sedentary time was observed in step counter users regardless of having such interventions or not. Yet it should be acknowledged that conclusions from indirect comparisons (subgroup analyses) are less reliable compared

### TABLE 2. Subgroup Analyses

| Subgroups                  | No. of Studies (No. of Subjects) | Effect Size | Heterogeneity |
|----------------------------|----------------------------------|-------------|---------------|
| Step goal use              |                                  |             |               |
| With                       | 11 (1594)                        | −0.32       | 68 0.001      |
| 10,000 steps/d             | 3 (367)                          | −0.16       | <1 0.15       |
| Alternative goals          | 8 (1227)                         | −0.43       | 76 <0.01      |
| Without                    | 4 (1668)                         | −0.09       | 38.7 0.18     |
| Components on SB          |                                  |             |               |
| With                       | 7 (956)                          | −0.29       | 61 0.02       |
| Without                    | 8 (2306)                         | −0.17       | 66.8 0.004    |
| ST measurement             |                                  |             |               |
| Questionnaires             | 8 (2330)                         | −0.09       | 24.5 0.23     |
| Instruments \(^1\)         | 7 (932)                          | −0.52       | 76 <0.01      |

CI = confidence interval, SB = sedentary behavior, ST = sedentary time.

\(^{1}\) Effect size was calculated using a random-effects model.

\(^{1}\) Accelerometer-measured sedentary time from the study by De Greef et al\(^{18}\) (2011) was used in this meta-analysis.

### TABLE 3. Univariate Weighted Random-Effects Meta-Regression Models

| Covariates                  | No. of Studies | Coefficients | 95% CIs | P   |
|-----------------------------|----------------|--------------|---------|-----|
| Baseline age \(^{a}\)       | 14             | −0.055       | −1.42 to 1.31 | 0.93 |
| Baseline BMI                | 10             | −0.039       | −0.13 to 0.049 | 0.33 |
| Sex (proportion of females) | 15             | −0.15        | −0.86 to 0.57 | 0.66 |
| Length of intervention      | 15             | 0.009        | −0.0073 to 0.025 | 0.26 |
| Baseline sedentary time     | 14             | −0.000863    | −0.006 to 0.0005 | 0.91 |
| Baseline walking steps      | 8              | 0.00004      | −0.0003 to 0.0004 | 0.79 |
| Changes in walking steps    | 8              | −0.00001     | −0.0007 to 0.0005 | 0.69 |
| Baseline light physical activity | 4           | 0.003        | −0.032 to 0.039 | 0.72 |
| Changes in light physical activity | 4        | −0.008       | −0.077 to 0.061 | 0.66 |
| Baseline moderate physical activity | 4        | 0.007        | −0.042 to 0.055 | 0.61 |
| Changes in moderate physical activity | 4      | 0.007        | −0.11 to 0.13   | 0.83 |
| Baseline vigorous physical activity | 4       | 0.03         | −0.12 to 0.17   | 0.52 |
| Changes in vigorous physical activity | 4       | 0.03         | −1.06 to 1.12   | 0.92 |
| Baseline MVPA               | 7              | 0.003        | −0.019 to 0.026 | 0.73 |
| Changes in MVPA             | 7              | −0.02        | −0.079 to 0.029 | 0.29 |
| Baseline total physical activity | 6           | −0.001       | −0.0049 to 0.003 | 0.54 |
| Changes in total physical activity | 6       | −0.01        | −0.043 to 0.024 | 0.46 |

BMI = body mass index, CI = confidence interval, MVPA = moderate-to-vigorous physical activity.

\(^{a}\) Age data were logarithmic transformed.
with those from head-to-head trials. Future studies using randomized controlled designs are worth being conducted to assess whether the supplementation of components on reducing sedentary behaviors to step counter use would give any additional benefits on sedentary time reduction.

The method of sedentary time measurement makes a substantial difference in the observed effect sizes in reducing sedentary time among step counter users, which may in part reflect a greater sensitivity or accuracy of objective methods in assessing sedentary time compared with subjective methods. However, it cannot be completely ruled out that this discrepancy might be also due to the potential differences of the step counter interventions (clinical heterogeneity). Subjective measurement using questionnaires such as IPAQ have been validated in epidemiological studies, but uncertainty remains regarding their relation to the objective measurement using devices such as accelerometers. Despite a moderate correlation observed between these 2 methods in measuring sedentary time, it is noted that the sedentary time is still largely underestimated using subjective versus objective methods. Besides, it should be noted that any of the objective methods that were used in the included studies of this meta-analysis cannot detect specific domains of sedentary time, such as the time spent using computers, watching TV, or sitting at work. Therefore, as also suggested by Healy et al, future studies would benefit from the incorporation of both methods, not only for measuring the total sedentary time, but also for capturing the domain-specific sedentary time and for exploring the patterns of sedentary time accumulation.

In recent years, there is an ongoing controversy with regard to the association between physical activity and sedentary time. The systematic review from Mansoubi et al suggested that the time from sedentary behaviors and light physical activity would be reallocated from one to another, which is sometimes also referred to “displacement hypothesis.” However, Pearson et al pointed out in a more conservative way that, although sedentary behaviors are inversely associated with physical activity, their relationship is so weak that the reallocation of time from sedentary behaviors to physical activity should not be considered in a simplified or direct manner. Besides, a cross-sectional survey has shown that the patterns in physical activity and sedentary behaviors may be mutually exclusive, indicating that there might be no real correlation between the time spent being physically active or sedentary. Partly in line with these, our meta-regression analyses also do not show any clear or strong evidence regarding the association between changes in sedentary time and any forms of physical activity.

The current findings from our study provide evidence in support of the widespread recommendation and adoption of step counter use in health promotion programmes. Moreover, our study gives a potential explanation for the observed effect sizes in reducing sedentary time among step counter users, which may in part reflect a greater sensitivity or accuracy of objective methods in assessing sedentary time compared with subjective methods. However, it cannot be completely ruled out that this discrepancy might be also due to the potential differences of the step counter interventions (clinical heterogeneity). Subjective measurement using questionnaires such as IPAQ have been validated in epidemiological studies, but uncertainty remains regarding their relation to the objective measurement using devices such as accelerometers. Despite a moderate correlation observed between these 2 methods in measuring sedentary time, it is noted that the sedentary time is still largely underestimated using subjective versus objective methods. Besides, it should be noted that any of the objective methods that were used in the included studies of this meta-analysis cannot detect specific domains of sedentary time, such as the time spent using computers, watching TV, or sitting at work. Therefore, as also suggested by Healy et al, future studies would benefit from the incorporation of both methods, not only for measuring the total sedentary time, but also for capturing the domain-specific sedentary time and for exploring the patterns of sedentary time accumulation.

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The current findings from our study provide evidence in support of the widespread recommendation and adoption of step counter use in health promotion programmes. Moreover, our study gives a potential explanation for the observed health benefits resulting from step counter use including weight loss, because epidemiological evidence suggests that decreased sedentary time is associated with reduced BMI, in which reduction is assumed to be independent of increased physical activity. In addition, there is emerging evidence that frequent interruptions from sedentary time are associated with an improved metabolic profile including reduced waist circumference and BMI. It seems likely that weight loss resulted from step counter use could be also related to the breaks in sedentary time, at least partly. However, to date, very few studies with very small sample sizes have focused on this topic and showed only some trends. More RCTs with larger sample sizes are therefore required to address this concern in future.

The main strengths of this meta-analysis include an extensive literature search, a reasonably large sample size, and comprehensive summaries of the effects of step counter use on sedentary time, along with the exploration of heterogeneity using a broad range of study and intervention characteristics as covariates. However, when interpreting these results, several limitations must be considered. First, the search strategy used in this meta-analysis was restricted to English-language studies, which might lead to a language or cultural bias. Moreover, a publication bias was detected using either Begg test or Egger test, increasing the risk of reporting bias resulting from possible small-study effects. However, the trim and fill method suggested that, the overall effect size derived from the currently included studies was unlikely to be affected by publication bias. Second, as indicated in the previous studies because step counter interventions generally included some other components (eg, step goals, promotions of sedentary behavior changes), it is difficult to establish their independent contributions to the observed effect sizes. Third, there existed some evidence of heterogeneity across studies, which were just partly explained by the use of step goals and the methods used for sedentary time measurement (subgroup analyses). This would somehow weaken the robustness of our main findings. Moreover, meta-regression analyses might have limited power to detect significant predictors that moderate the sedentary time changes related to pedometer intervention or explain the potential sources of heterogeneity. Fourth, the high dropout rates and the attrition bias reported in this meta-analysis might downgrade the evidence level. Fifth, although this meta-analysis shows that step counter use was associated with an overall reduction in sedentary time of ~23 min/d, it remains unknown whether changes of this magnitude are sufficient to benefit healthy outcomes. Finally, this meta-analysis fails to show evidence regarding the effects of step counter use in workplace settings in reducing sedentary time among adults because several included studies did not clearly state whether the step counters were used for workplace interventions.

In summary, this study provided evidence that step counter use leads to reduced sedentary time in adults, and the step goal setting is an important predictor of reduced sedentary time. Future studies are required to specify the goal use among step counter users to employ objective and subjective methods for measuring both total and domain-specific sedentary time, to address the magnitude of reductions in sedentary time sufficient to benefit healthy outcomes, and to investigate the effects of step counter use on breaking up the prolonged sedentary time to gain additional health benefits.

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