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Systematic Review or Meta-analysis

Pedometer intervention and weight loss in overweight and obese adults with Type 2 diabetes: a meta-analysis

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Abstract

Aim Although pedometer intervention is effective in increasing physical activity among adults with Type 2 diabetes, its impact on weight loss remains unclear. This meta-analysis was aimed to assess whether pedometer intervention promotes weight loss.

Methods Three different databases were searched for randomized controlled trials (RCTs) published in English up to April 2015. Studies were included if they investigated the effects of pedometer intervention on weight loss, as measured by BMI or weight. Effect sizes were aggregated using a random-effects model. Subgroup and meta-regression analyses were used to identify potential moderators. Eleven RCTs with 1258 participants were included. All enrolled participants were overweight or obese.

Results Pedometer intervention led to significantly decreased BMI [weighted mean difference (WMD) −0.15 kg/m^2, 95% confidence interval (CI) −0.29 to −0.02 kg/m^2] and reduced weight (WMD −0.65 kg, 95% CI −1.12 to −0.17 kg). Dietary counselling seemed to be a key predictor of the observed changes. However, none of the following variables had a significant influence: step goal setting, baseline age, BMI, weight, sex distribution, disease duration, intervention duration, and baseline values or change scores for total or moderate-to-vigorous physical activity. After completion of the pedometer intervention, non-significant declines in BMI and weight were observed during the follow-up periods.

Conclusions Pedometer intervention promotes modest weight loss, but its association with physical activity requires further clarification. Future studies are also required to document dietary and sedentary behaviour changes to facilitate the use of pedometers for weight loss in overweight and obese adults with Type 2 diabetes.

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Introduction

Emerging evidence shows that there is a J-shaped association between weight status as assessed by BMI and all-cause mortality in adults with incident Type 2 diabetes [1]. The evidence further points out that adults with Type 2 diabetes who were overweight or obese at diagnosis have higher mortality rates compared with their normal-weight counterparts [1]. Although intensive lifestyle intervention that promotes weight loss may not reduce the risk of cardiovascular morbidity or mortality [2], increasing evidence suggests that weight loss has clinically meaningful benefits in improving glycaemic control, lipid profiles, renal function, blood pressure and quality of life among adults with Type 2 diabetes [3–6].

Pharmacological and surgical approaches are recognized as being highly effective in achieving substantial weight loss [7,8], and dietary energy restriction is considered largely responsible for the initial weight loss in lifestyle-intervention programmes [9,10]. However, regular physical activity, another important component of lifestyle intervention, remains a cornerstone in weight management [9,11]. In recent years, pedometer intervention designed for physical activity promotion and health improvement, including weight loss, has become increasingly popular among adults with Type 2 diabetes [12–24]. Although previous studies have clearly shown that pedometer intervention is remarkably effective in increasing physical activity among adults

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with Type 2 diabetes [24,25], its effectiveness in losing weight remains poorly delineated. Moreover, although some studies pointed out that pedometer intervention is effective in decreasing BMI and reducing body weight, their analyses were conducted on highly heterogeneous populations [26,27], making it questionable whether such conclusions could simply be transferred to adults with Type 2 diabetes. Furthermore, findings on weight loss through pedometer intervention are generally inconsistent across currently published randomized controlled trials (RCTs) [8,12,21], with most of showing no statistically significant reductions in weight [13,15,18–20,23] and some having very limited statistical power due to the small sample sizes [13,18].

In addition, preventing weight regain after successful weight loss interventions remains a great challenge [9], with poor adherence to increased or regular physical activity in the follow-up periods one of the major contributing factors [28]. Although there is evidence that the increased physical activity associated with pedometer intervention can be sustained in the follow-up periods among adults with Type 2 diabetes [15,20], it would be interesting to know whether a similar pattern for weight loss exists, given the important role of physical activity in weight management [9,11].

Therefore, the primary objective of this meta-analysis of RCTs was to investigate the impact of pedometer intervention on weight loss, as assessed by net BMI and weight changes in adults with Type 2 diabetes. The secondary objective was to evaluate whether pedometer intervention has a late effect on weight loss to prevent weight regain during the follow-up periods.

Methods

This meta-analysis was conducted and reported according to the outlines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [29], and adhered to a prospectively registered protocol (PROSPERO CRD42015023178).

Data sources and search strategies

A structured and systemic literature search was conducted in the following databases up to 10 April 2015: PubMed, the Cochrane Central Register of Controlled Trials and Web of Science, using terms related to pedometer, Type 2 diabetes and RCTs (Table S1). In addition, reference lists of the retrieved relevant review article, systematic review and/or meta-analysis were checked manually to search for more potentially suitable literature.

Study selection

Studies were included if: (1) all participants were adults (mean age ≥ 18 years) and had been diagnosed with Type 2 diabetes; (2) they received interventions using pedometers as motivational tools to increase unstructured activity (daily movement) with a minimum duration of 4 weeks, as suggested by Richardson *et al.* [27] and Hultquist *et al.* [30]; (3) they were compared with control groups that did not receive any pedometer interventions or used pedometers only to record daily steps; (4) they reported outcomes assessing the effects of pedometer interventions on weight loss, as measured by BMI or weight [31] (primary outcome), or their sustained effects in the follow-up periods after the completion of pedometer interventions (secondary outcome); and (5) they were RCTs and were published in English. Studies were excluded if the data of interest were not reported or could not be obtained after contacting the corresponding authors via emails. Studies were also excluded if they were not published in full-texts (e.g. letters) [21], because of their limited information regarding the descriptions of the control and intervention details.

Data extraction and quality assessment

Following the literature search and the removal of duplicates, the titles, abstracts or full-texts of the retrieved publications were reviewed to select potentially eligible studies based on the inclusion and exclusion criteria. Data were extracted using a structured form, which included general information on the included studies (authors and year of publication), characteristics of enrolled participants [sample sizes, sex distribution (proportion of women), disease duration and baseline mean age, weight, BMI and physical activity], details of pedometer interventions (intervention duration, follow-up period after the completion of pedometer interventions, step goal setting and dietary counselling) and their respective controls, outcome variables of interest (net changes in BMI or weight from baseline) and some other data (dropout rates and countries of origin).

The methodological quality of each included RCT was evaluated using the Cochrane Collaboration's 'Risk of Bias' tool [32]. This tool includes six items in general, which are random sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias) and selective reporting (reporting bias). Based on the criteria for risk of bias judgement described in the Cochrane Handbook [32], each item was judged to be of low, unclear or high risk of bias.

Two researchers (S.Q. and X.C.) performed the literature selection, data extraction and quality assessment. Disagreements between researchers were resolved through discussion with a third researcher (U.S.) when they occurred.

Data synthesis and statistical analysis

Net mean change from baseline in BMI or weight (in kg) and its SD for each group from each study were calculated if they were not reported, using the formulas provided by Cochrane Handbook [32]. Specifically, the SD of the mean change was imputed using a correlation coefficient as suggested [32], which was calculated to be 0.98 for both intervention and control groups based on the reported data [22]. When a study reported data of BMI and/or weight for more than one time-point, data from the last available time-point were chosen. Finally, if one study compared more than one pedometer intervention with the same control group, these intervention groups were combined into one to overcome the unit-of-analysis error resulted from double counting of the participants in the 'shared' group [32].

All available data related to the primary or secondary outcome were pooled using a random-effects model to assess the summary effect size estimates [i.e. weighted mean differences (WMDs)] with the corresponding 95% confidence intervals (95% CI) [32]. Heterogeneity was examined using the Cochrane Q and I^2 statistics, with either the P-value for the Cochrane Q statistic < 0.10 or $I^2 \geq 50\%$ indicative of substantial heterogeneity. Subgroup analyses were conducted to examine the associations of pedometer intervention with weight loss on the basis of step goal setting (with vs. without), dietary counselling (with vs. without) and data analysis (intention-to-treat vs. per-protocol analyses). Univariate weighted random-effects meta-regression analyses were also performed to identify the potential modifiers (source of heterogeneity) of BMI or weight changes based on the characteristics of participants and pedometer interventions. These modifiers included baseline mean age, weight, BMI, sex distribution and disease duration, pedometer intervention duration, as well as baseline and change scores for total physical and moderate-to-vigorous physical activity. Specifically, total physical activity was assessed using pedometers or accelerometers with the unit of steps/day, and moderate-to-vigorous physical activity was measured using accelerometers or questionnaires with the unit of minutes/day. Sensitivity analyses were carried out to assess the robustness of the findings by removing each individual study sequentially. Publication bias was assessed quantitatively using the Begg's rank correlation test and the Egger's asymmetry test, with either of the $P < 0.10$ considered to be significant.

The above analyses were conducted mainly on the primary outcome (that is, the immediate post-intervention effect of pedometer intervention on weight loss), because it was later found that only two studies [15,23] reported the secondary outcome (i.e. the late effect of pedometer intervention on weight loss in the follow-up periods). All analyses were performed using STATA software (v. 12.0, College Station, Texas, USA) and Review Manager (v. 5.2, the Nordic Cochrane Centre, Copenhagen, Denmark). A two-tailed $P < 0.05$ was considered statistically significant, unless otherwise stated.

Results

Of the 261 unique studies identified, a total of 11 RCTs [12–20,22,23] met the inclusion criteria and were included in the current meta-analysis upon the removal of duplicate and the review of title, abstract and full-text (Fig. 1). All the included RCTs (Table 1) were published as full paper articles between 2004 and 2013. The sample sizes of individual RCTs varied from 30 to 494 participants, and the mean ages of enrolled participants ranged from 49.0 to 68.3 years. All participants were overweight or obese, and had baseline mean BMI > 25.0 or 30.0 kg/m^2. The durations of pedometer interventions lasted from 6 to 48 weeks. Of the included RCTs, seven clearly stated the use of step goals [13–16,18,22,23], while the other four failed to specify [12,17,19,20]. Besides, two RCTs provided dietary counselling in addition to pedometer intervention [12,17], and two reported follow-ups after the completion of pedometer intervention, assessing the sustained effect of pedometer intervention on weight loss [15,23]. The majority of the RCTs had been conducted in North American or European countries. Four RCTs had dropout rates > 20% [14,17,20,22]. The methodological quality of included RCTs was low to moderate in general. Among them, six did not describe the methods of randomization [13,14,17,18,22,23], and five used per-protocol analyses rather than intention-to-treat analyses [14,17,18,20,22], leading to the potentially high risk of attrition bias of these studies (Table S2).

Immediate post-intervention effect of pedometer intervention on weight loss

Eight RCTs with 1130 participants reported immediate post-intervention outcomes on BMI related to pedometer intervention [12,13,15,16,18–20,23], and seven RCTs enrolling 805 participants reported such outcomes on weight [13–15,17,18,22,23]. The mean net BMI (BMI post-intervention minus pre-intervention) was −0.14 kg/m^2 (SD 0.37 kg/m^2) for control groups and −0.3 kg/m^2 (SD 0.46 kg/m^2) for pedometer interventions. The mean net weight (weight post-intervention minus pre-intervention) was −1.12 kg (SD 1.34 kg) for control groups and −1.34 kg (SD 1.38 kg) for pedometer interventions. The meta-analyses showed that pedometer intervention was associated with a significant decrease in BMI (WMD −0.15 kg/m^2, 95% CI −0.29 to −0.02 kg/m^2; I^2 = 18.7%, P for heterogeneity = 0.28; Fig. 2), and a significant reduction in weight (WMD −0.65 kg, 95% CI −1.12 to −0.17 kg; I^2 <1%, P for heterogeneity = 0.80; Fig. 3) when compared with controls.

Subgroup analyses showed that pedometer intervention with dietary counselling resulted in significant declines in BMI (WMD −0.30 kg/m^2, 95% CI −0.50 to −0.10 kg/m^2) and weight (WMD −0.86 kg, 95% CI −1.45 to −0.27 kg) compared with controls who received dietary counselling. However, pedometer intervention alone showed only some

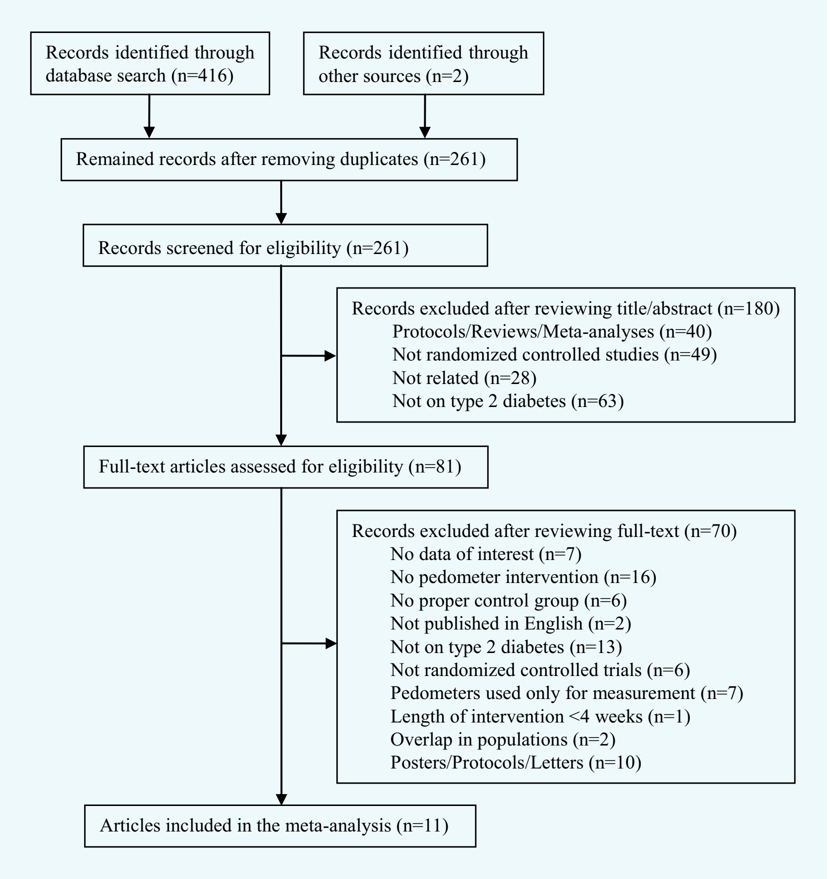

FIGURE 1 Flowchart of included studies.

trends towards decreased BMI and reduced weight compared with controls lacking dietary counselling (Table 2). Step goal setting did not predict any significant changes in BMI or weight (Table 2). Interestingly, RCTs employing intention-to-treat analyses showed that pedometer intervention significantly decreased BMI (WMD −0.22 kg/m^2, 95% CI −0.39 to −0.05 kg/m^2) and reduced weight (WMD −0.77 kg, 95% CI −1.28 to −0.25 kg). Meta-regression analyses revealed that none of the variables described in the Methods section significantly influenced the BMI or weight outcome related to pedometer intervention (Table 3). Sensitivity analyses by excluding one RCT at a time showed that both BMI and weight outcomes were not substantially affected by any particular study in general. No evidence of publication bias was detected for BMI outcome (Begg's test, P = 0.71; Egger's test, P = 0.70), while some minor bias was observed for weight outcome using Egger's test (P = 0.02) but not using Begg's test (P = 0.76).

Late effect of pedometer intervention on weight loss in follow-up periods

Two RCTs involving 133 participants reported follow-up outcomes on both BMI and weight after the completion of pedometer intervention [15,23], with a mean follow-up period of 33.5 weeks (Table 1). During this period, one RCT utilized a booster session aiming to help participants in the pedometer intervention group to increase self-efficacy and set up long-term action plans [15], and the other had no further intervention [23]. The meta-analyses showed that participants who received pedometer intervention exhibited some, albeit non-significant declines in BMI (WMD −0.21 kg/m^2, 95% CI −1.06 to 0.65 kg/m^2) and weight (WMD −0.05 kg, 95% CI −1.06 to 0.95 kg) compared with controls who did not receive such intervention during the follow-up periods.

Discussion

Summary

To our knowledge, this is the first meta-analysis of RCTs addressing the impact of pedometer intervention on BMI and weight among adults with Type 2 diabetes; in particular, among those who are overweight or obese. This study provides evidence that pedometer intervention led to modestly but significantly decreased BMI and reduced weight compared with controls, and dietary counselling seemed to be a key predictor of these changes. However, we did not find

Table 1 Characteristics of each included RCT

Source	Characteristics of participants*				Intervention and control groups	Intervention details		
	Sample size†	Age, year	BMI, kg/m²	Weight, kg		Duration, weeks	Dietary advice	Step goal
Andrews *et al.*, 2011 [12]	246	60.0	31.6	91.1	Intervention: received pedometer-based walking interventions and dietary consultation with nurse support.	48	With	NS
	248	60.1	31.5	90.2	Control: received dietary consultation with nurse support.			
Araiza *et al.*, 2006 [13]	15	49	30.0	NA	Intervention: received pedometer-based walking interventions.	6	Without	Yes
	15	51	33.5	NA	Control: were asked to maintain normal activity habits.			
Bjorgaas *et al.*, 2008 [14]	23	56.4	31.2	94.8	Intervention: received pedometers and were encouraged to increase daily time on walking.	24	Without	Yes
	25	61.2	31.5	95.2	Control: were encouraged to increase daily time on walking.			
De Greef *et al.*, 2010‡ [15]	20	61.3	29	83.5	Intervention: received cognitive–behavioural pedometer-based interventions.	12	Without	Yes
	21	61.3	31.5	92.6	Control: received usual care.			
De Greef *et al.*, 2011§ [16]	43	68.3	29.7	NA	Intervention: received pedometer-based physical activity programmes with individual or group counselling.	12	Without	Yes
	24	66.0	31.5	NA	Control: received general care.			
Diedrich *et al.*, 2010 [17]	16	56.7	NA	94.8	Intervention: received pedometer-based programmes, books (Manpo-kei) and usual diabetes education.	12	With	NS
	17	54.9	NA	107.1	Control: received usual diabetes education.			
Engel and Linder 2006 [18]	22	60.5	32.7	91.9	Intervention: received pedometers and health-related coaching.	24	Without	Yes
	28	64	31.2	84.9	Control: only received health-related coaching.			
Kirk *et al.*, 2009§ [19]	99	62.1	32.8	NA	Intervention: received pedometers, physical activity consultation and telephone call.	48	Without	NS
	35	59.2	34.9	NA	Control: received standard care and telephone call.			
Plotnikoff *et al.*, 2013§ [20]	139	61.8	30.2	NA	Intervention: received pedometers, theory-based behavioural interventions and physical activity education.	48	Without	NS
	83	61.0	30.2	NA	Control: received standard physical activity education.			
Tudor-Locke *et al.*, 2004 [22]	24	52.8	34.1	96.8	Intervention: received pedometers with instructions for goal-setting and motivational postcards.	16	Without	Yes
	23	52.5	32.5	92.3	Control: only received motivational postcards for thanks.			
Van Dyck *et al.*, 2013‡ [23]	60	62	30.2	89.2	Intervention: received pedometer-based physical activity interventions with telephone support.	24	Without	Yes
	32		29.7	84.5	Control: received usual care.			

*Data for age, BMI, weight were imputed using baseline mean values.
†Number of participants included in the per-protocol or intention-to-treat analyses.
‡Reported follow-up data of BMI and weight after the completion of pedometer interventions.
§Included two intervention groups and both were combined into one group.
NS, not specified; NA, not applicable.

clear evidence that these changes were likely to be moderated by baseline age, BMI or weight, sex distribution, disease duration, intervention duration, baseline values or change scores of total or moderate-to-vigorous physical activity, as well as the presence of step goal setting. Moreover, the evidence remains insufficient regarding the late or the sustained effects of pedometer intervention in losing weight or preventing weight regain in the follow-up periods due to the limited number of studies.

Interpretations

The main findings of our study are generally consistent with those observed in the previous systematic review and meta-analysis, which reported comparable modest declines in BMI (WMD −0.38 kg/m², 95% CI −0.72 to −0.05 kg/m²) and weight (WMD −1.27 kg, 95% CI −1.85 to −0.70 kg) associated with pedometer intervention [26,27]. However, one should keep in mind that both studies failed to specify

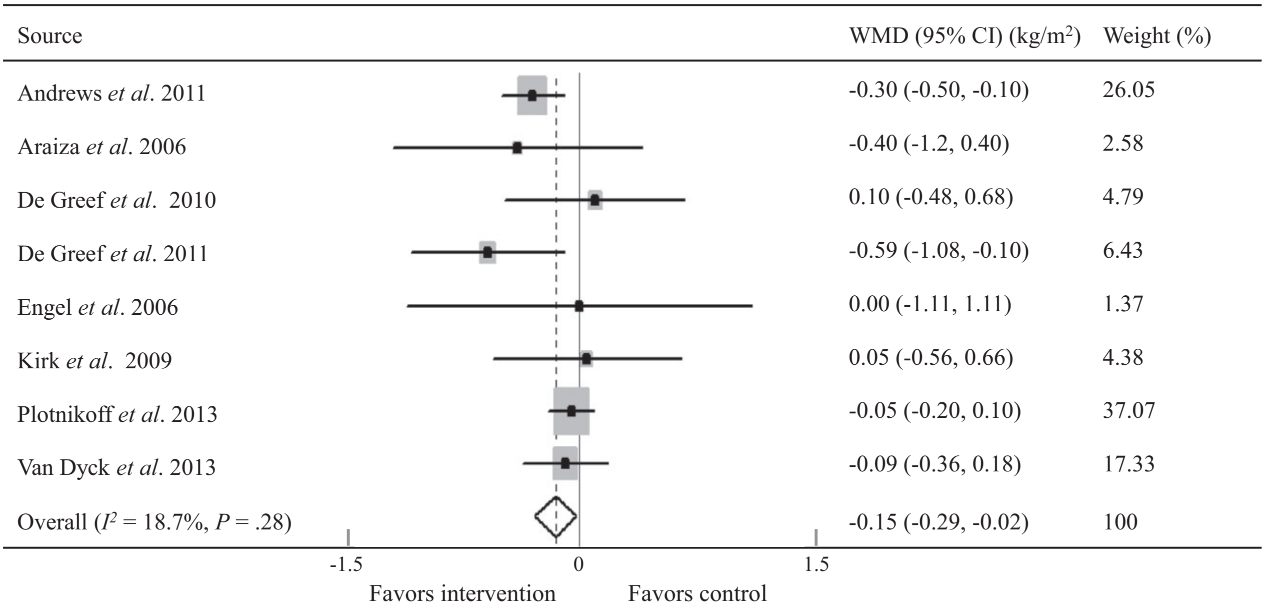

FIGURE 2 Forest plot for net changes in BMI using a random-effects model. WMD, weighted mean difference; CI, confidence interval. Andrews *et al.* [12], Araiza *et al.* [13], De Greef *et al.* [15,16], Engel and Linder [18], Kirk *et al.* [19], Plotnikoff *et al.* [20], Van Dyck *et a*l. [23].

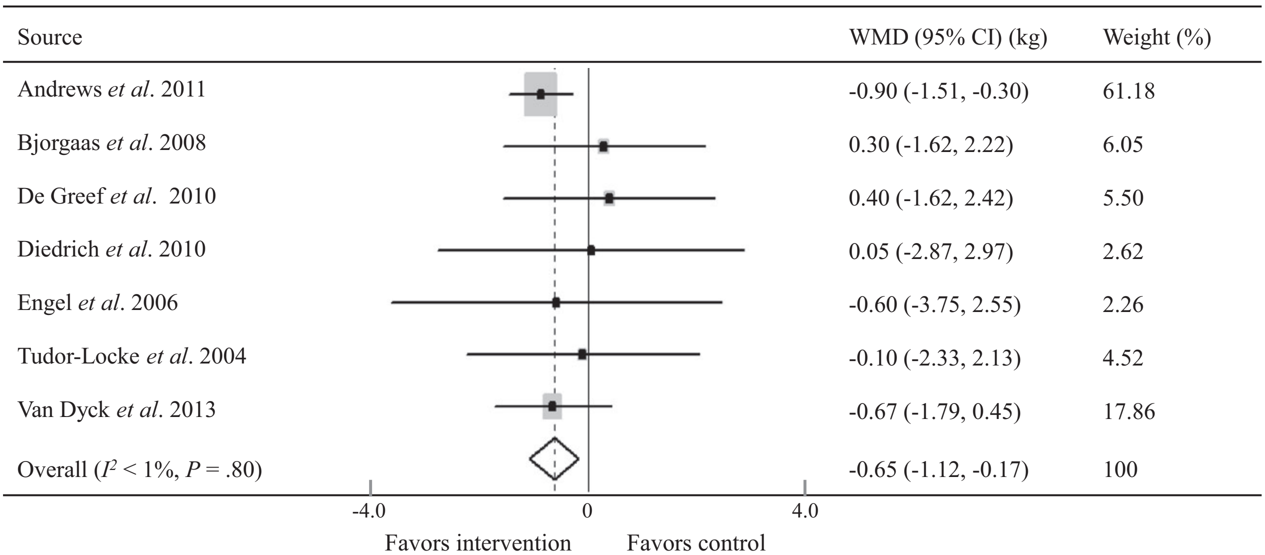

FIGURE 3 Forest plot for net changes in weight using a random-effects model. WMD, weighted mean difference; CI, confidence interval. Andrews *et al.* [12], Bjorgaas *et al.* [14], De Greef *et al.* [15], Diedrich *et al.* [17] Engel and Linder [18], Tudor-Locke *et al.* [22], Van Dyck *et al.* [23].

these effects among a particular population such as patients with Type 2 diabetes, who are more likely to be overweight or obese [1] and might show greater difficulties in losing weight compared with the population without diabetes [33,34]. Moreover, they did not restrict studies to RCTs, lowering their degree of generalizability and subsequently the level of evidence. In addition, Bravata *et al.* found that having a step goal and older age were key predictors of reduced BMI among pedometer users [26], and Richardson *et al.* observed that longer duration of pedometer intervention was associated with more weight reduction [27]. However, in contrast to their findings, our subgroup and meta-regression analyses did not identify these moderators. It seems likely that the different target populations and the different study selection criteria might largely contribute to these discrepancies. There is some evidence suggesting that compared with pedometer intervention alone, participants would achieve more weight loss by adding an additional dietary component, such as dietary counselling, which could reinforce the implementation of individual dietary

Table 2 Subgroup analyses for BMI and weight

	BMI			Weight		
		Effect size (kg/m^2)			Effect size (kg)	
Subgroups	No. studies (subjects)	WMD	95% CI	No. studies (subjects)	WMD	95% CI
Step goal use						
With	5 (280)	−0.18	−0.41 to 0.05	5 (278)	−0.27	−1.06 to 0.52
Without	3 (850)	−0.14	−0.34 to 0.06	2 (527)	−0.86	−1.45 to −0.27
Dietary counselling						
With	1 (494)	−0.30	−0.50 to −0.10	2 (527)	−0.86	−1.45 to −0.27
Without	7 (636)	−0.09	−0.20 to 0.03	5 (278)	−0.27	−1.06 to 0.52
Data analysing						
ITT analysis	6 (858)	−0.22	−0.39 to −0.05	3 (627)	−0.77	−1.28 to −0.25
Per-protocol analysis	2 (272)	−0.05	−0.20 to 0.10	4 (178)	0.01	−1.12 to 1.21

Table 3 Univariate weighted meta-regression analyses for BMI and weight

	BMI			Weight		
Variables	No. of studies	Coefficient	*P*	No. of studies	Coefficient	*P*
Baseline mean age*	8	−0.24	0.89	7	−4.15	0.57
Sex distribution†	7	0.01	0.21	7	0.02	0.64
Baseline BMI/weight	8	−0.11	0.19	7	0.05	0.60
Disease duration	4	−0.005	0.96	4	−0.03	0.40
Baseline total PA‡	6	0.00007	0.54	3	0.008	0.53
Changes in total PA‡	6	−0.0001	0.36	3	0.001	0.54
Baseline MVPA§	4	−0.02	0.33	NA	NA	NA
Changes in MVPA§	4	−0.04	0.13	NA	NA	NA
Intervention duration	8	0.003	0.62	7	−0.03	0.21

*Age data were log-transformed.
†It represented the proportion of women.
‡Physical activity was assessed using pedometers or accelerometers with the unit of steps per day.
§MVPA was assessed using accelerometers (objective methods) in two studies [12,15] and questionnaires (subjective methods) in the other two studies [16,20].
PA, physical activity; MVPA, moderate-to-vigorous physical activity; NA, not applicable.

management [27]. Partly in support of this, our indirect comparison showed that pedometer intervention in conjunction with dietary counselling seemed to yield more reductions in BMI and weight than pedometer intervention alone, although these results were found to be statistically non-significant. Yet it is important to acknowledge that such reductions might be underestimated, because the control group used in the subgroup analysis of the combined effects of pedometer intervention with dietary counselling on weight loss received dietary counselling, while the one in another subgroup analysis did not. Therefore, more RCTs with head-to-head study designs are required in the future to address the additional effects of dietary counselling in pedometer users. Our meta-regression analyses also showed that the modest weight loss related to pedometer intervention seemed to be non-significantly associated with the baseline values or the change scores of total physical activity (presented as steps/day), which is in agreement with the results reported in the previous study [26]. Given the accumulating evidence that moderate-to-vigorous physical activity leads to reduced weight regardless of its amount [35,36], one possible explanation for our findings is that the intensity of physical activity seems to be essential in the weight management. However, meta-regression analyses from our meta-analysis did not show adequate evidence that moderate-to-vigorous physical activity was related to the weight loss associated with pedometer use. This is likely due to the limited power of meta-regression analysis to detect the significant moderator, since our meta-regression analyses were conducted using the averages of patient characteristics for each RCT rather than the individual patient data. Moreover, the potential heterogeneity of the methods used to assess the moderate-to-vigorous physical activity (objective vs. subjective methods [37], Table 3) might also lead to the inconsistency.

There are some other explanations for the observed declines in BMI and weight resulting from pedometer intervention among overweight and obese adults with Type 2 diabetes. It is well documented that participants with Type 2 diabetes who received pedometer intervention would become more active than those who did not receive such intervention [24,38]. Given the fact that physically active participants are more likely to have better healthy eating index scores [39], lower fat intake, and more dietary restraint compared with those who are physically inactive [40], it is plausible that pedometer intervention would lead to subsequent weight loss due changes in dietary behaviour. However, none of the included studies assessed such change. In addition to that, sedentary behaviour change might be another possible explanation for our findings, because pedometer use results in significantly reduced sedentary time [12,41], which is shown to be associated with decreased BMI [42,43]. However, only two of the included studies recorded sedentary behaviour change using accelerometers, and both failed to investigate this relationship [12,15].

It should be also mentioned that these declines in BMI and body weight were modest, which might be due in part to the fact that none of the included studies was initially or specifically designed to assess the effects of pedometer interventions on weight loss. In addition, participants with Type 2 diabetes showed somehow poor compliance with the pedometer invention programmes, with adherence rates of only around 80% [15,20,22] together with high dropout rates of > 20% [14,17,20,22]. Moreover, it is well-recognized that diabetes medication, such as metformin, sulfonylureas, insulin and glucagon-like peptide–1 receptor agonists, potentially affect body weight; however, almost all included studies failed to assess such confounding effects following pedometer interventions. Furthermore, as indicated by our subgroup analyses (intention-to-treat vs. per-protocol analyses), the approaches for handling missing data could also influence the final outcomes. Therefore, future research is required to address these concerns.

In addition to weight loss, preventing weight regain after successful weight loss is another key goal for a weight management programme [9]. Although our study did not find that pedometer intervention had a sustained effect in maintaining weight loss in the follow-up periods after the completion of the intervention, there is some evidence that pedometer intervention may have a late effect in preventing weight regain for patients with Type 2 diabetes. However, because of the limited number of studies included (only two), this finding was likely to be underestimated and deserves further attention. Consequently, more research is required on this topic. Moreover, in order to achieve further weight loss or maintain weight loss in the follow-up periods after pedometer intervention, studies that provide ongoing support, such as encouraging participants to use pedometers continuously or take part in telephone- [44] or web-based lifestyle interventions [45], should be given priority.

Strengths and limitations

Our study has some strengths, which include the use of a pre-specified protocol and the inclusion of only RCTs. In addition, because only one of the eight RCTs assessing changes in BMI reported statistically significant results [16], this highlights the superiority of a meta-analysis in identifying the important summary estimate with increased and improved statistical power (e.g. large sample size) and the necessity to conduct a meta-analysis in order to obtain stringent evidence.

Our study also has several limitations. First, despite undetected publication bias by the Begg's test or the Egger's test, there remains some possibility of this bias because of the unsearched 'grey literature' (e.g. dissertation) and the language restriction to English. Second, although this study did not find any significant moderators using meta-regression analyses, one should be aware of the possibility that meta-regression analyses may have limited power to detect these moderators. Third, the robustness of our findings from the meta-analysis might be weakened because of the selection bias that resulted from the enrolled participants who were all overweight or obese rather than a clinically representative population with Type 2 diabetes. Moreover, the robustness might be further weakened since there was some evidence of publication bias for the meta-analysis of weight. Fourth, the methodological quality of some included RCTs was judged to be low due to the attrition bias resulting from their per-protocol analyses, and this will lower the level of the current evidence obtained. Fifth, all included RCTs were conducted in high-income countries. It remains unknown whether these findings could be used as guides for participants from low- or middle-income nations to use pedometers. Sixth, although BMI and weight are well-recognized markers for assessing weight loss, it might be also useful to choose some other markers such as waist circumference and waist-to-hip ratio for analysis. However, our meta-analysis failed to do that. Finally, despite some observed weight loss related to pedometer intervention, it is of great interest to investigate whether there are any changes in body composition, such as body fat percentages or lean body mass. However, very few studies evaluated these changes [12,17], limiting the further exploration by using meta-analytical approaches consequently. Therefore, future studies are worth being conducted on this topic.

Conclusion

In conclusion, pedometer intervention is a promising approach for promoting weight loss in overweight and obese adults with Type 2 diabetes that modestly reduces BMI and weight. In order to better understand the association between pedometer intervention and weight loss, future studies are required to document the changes in physical activity, dietary behaviour and sedentary time, as well as to investigate changes in body composition. Furthermore, future studies are also required to provide ongoing support after pedometer intervention to maintain weight loss, and to analyse the cost-effectiveness of pedometer intervention for its better promotion, given the fact that pedometer is inexpensive, but its use only leads to a modest weight loss.

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Competing interests

None declared.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Search strategies.

Table S2. Bias assessment of each randomized controlled trials.