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Review

A systematic review of studies using pedometers to promote physical activity among youth

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ABSTRACT

Background. While pedometers have an important role to play in the promotion of lifestyle activity among adults, less known is regarding their impact on behavior among youth (i.e. children and adolescents). The primary aim of this review was to identify the effectiveness of pedometers in promoting physical activity among youth. Secondary aims were to assess the quality of existing studies and examine the different ways that pedometers have been used to promote activity.

Methods. A systematic search of six electronic databases was conducted using combinations of the following key words 'physical activity', 'walking', 'intervention', 'promotion', 'evaluation', and 'pedometer'. The quality of the studies was assessed against predetermined criteria.

Results. Our search identified 14 studies, of which 12 resulted in increases in physical activity. Three studies used pedometers as open-loop feedback mechanisms to increase physical activity by making access to sedentary activities contingent on achieving activity targets. Ten studies used pedometers for self-monitoring and one study incorporated pedometers into an integrated school curriculum.

Conclusions. Pedometers have been used successfully in a variety of ways to promote activity among youth. Since there are so few studies at this time, there is ample need and opportunity to contribute to the knowledge base.

Contents

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Introduction

Over the past two decades there has been a public health shift from a focus on exercise (intended to develop physical fitness) to an emphasis on promoting moderate intensity lifestyle physical activity (intended to improve health outcomes) (Biddle et al., 2004; Dunn et al., 1998; U.S. Department of Health and Human Services, 2000). Lifestyle activities include walking, cycling to work or school and taking the stairs instead of the elevator. A body of evidence has emerged demonstrating that significant health benefits can accrue from activity of moderate intensity that can be accumulated throughout the day (Church et al., 2007; U.S. Department of Health and Human Services, 1996).

Pedometers have emerged as self-monitoring tools for promoting lifestyle physical activity in a variety of populations. Pedometers provide valuable feedback about steps taken, distance covered, time spent in activity and/or an estimate of energy expenditure. The basic premise underlying the use of pedometers to increase physical activity is that the immediate visual feedback of cumulative step counts increase individuals' awareness of how their personal behavioural choice affects their physical activity. Used as part of a guided and repetitive self-monitoring, feedback, and goal-setting process, the pedometer is able to provide up-to-the-minute information which can be used to adjust these behavioural choices to achieve physical activity objectives.

Although recommendations for physical activity have traditionally been time and intensity-based (i.e. 30 min/day of moderate-to-vigorous physical activity at least five times a week), in response to the ubiquity of pedometers, daily targets of 10,000 steps/day for adults have emerged. However, Tudor-Locke and Myers (2001) have suggested that 10,000 steps/day is unrealistically high for low-active or sedentary adults and may contribute to low program adherence. The step recommendations for children and adolescents are equally problematic. While the President's Council on Physical Fitness and Sports recommends 13,000 steps/day for boys and 11,000 steps for girls (President's Council on Physical Fitness and Sports, 2002), a recent study examining the relationship between step-counts and body mass index (BMI) suggested that the step targets should be as high as 12,000 for girls and 15,000 for boys (Tudor-Locke et al., 2004). Having a standard step target may not be necessary and it has been

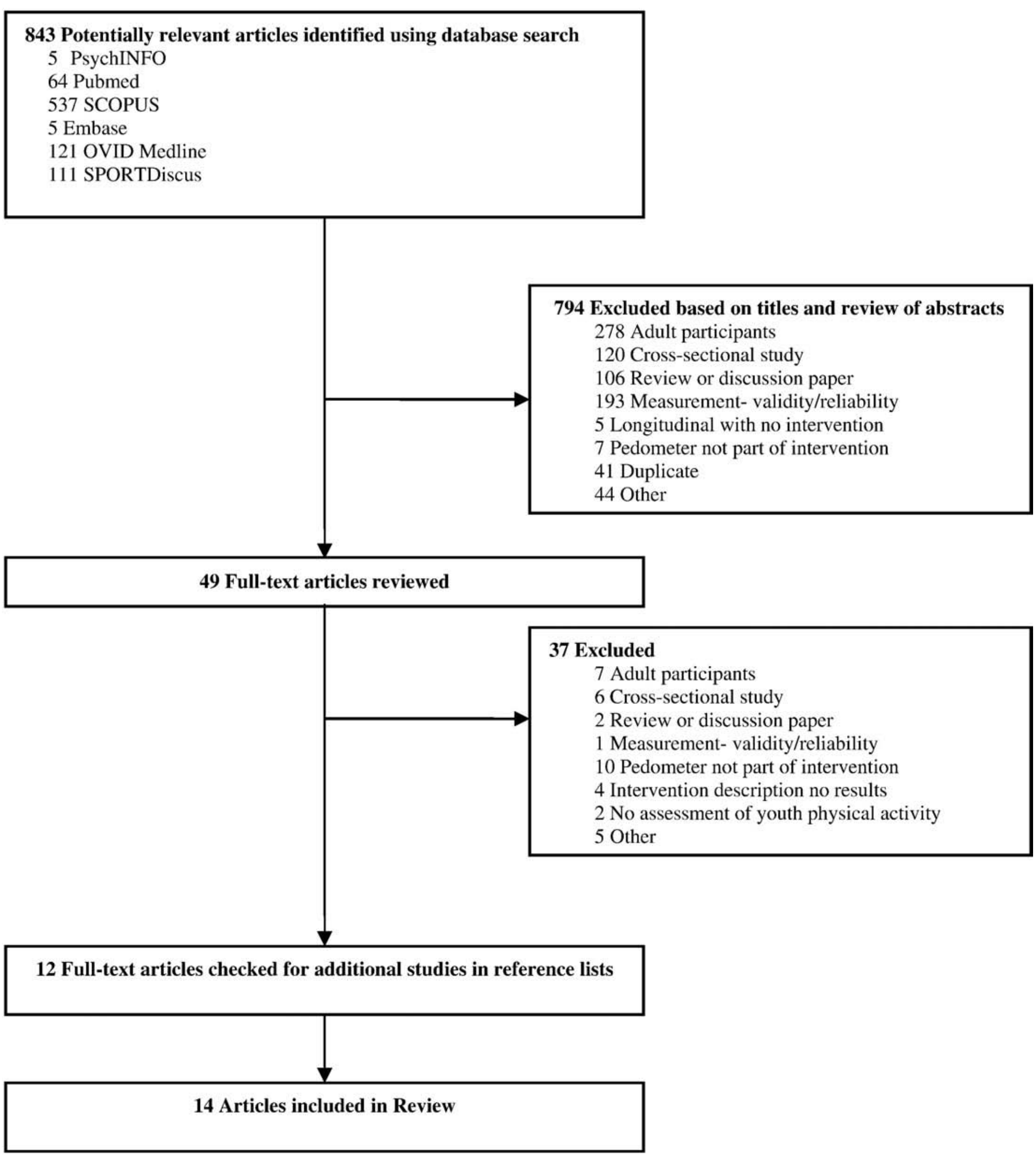

Fig. 1. Flow of studies through the review process.

Table 1
Studies that have used pedometers to promote physical activity among youth

Study	Sample	Design	PA measure	Description of pedometer intervention component	Assessment	Results
Goldfield et al. (2000)	United States 34 obese participants Mean age 10.4 (±1.4) years	EXP-2 groups Individual level randomization 2 INT and CON groups	TriTrac® accelerometry	Open-loop feedback experiment. In a single 20 min experimental session, children were required to accumulate 750 to 1500 PED counts to earn 10 min of access to video games or movies. Control group were provided with access to the sedentary behaviors non-contingently.	No baseline, physical activity assessed over a 20 min session	Participants in both INT groups recorded significantly more PA than control group.
Schofield et al. (2005)	Australia 85 low-active participants Mean age 15.8 (±.8) years	QEXP-3 groups School level allocation CON, time-based goal-setting INT and step-based goal-setting INT	4-days of unsealed PED monitoring PA questionnaire	School-based 12-week INT involving goal-setting and self-monitoring using either time-based PA goals or step based PA goals. Weekly meetings to discuss PA, goals and barriers. Weekly meetings to discuss PA, goals and barriers.	Baseline, mid-intervention (6-week) and posttest (12-week)	Step-based INT group significantly increased PA from baseline.
Lieberman et al. (2006)	United States 22 blind participants Age range 9–13 years	No CON group	7-days of unsealed PED monitoring (documented by parents)	Blind participants were provided with talking PEDs designed to promote walking behavior. Participants wore the PED during a 1-week activity camp designed to develop motor and fitness skills.	Baseline and 1-week of monitoring camp	Compared to baseline, boys and girls recorded higher step counts during the camp.
Southard and Southard (2006)	Canada 120 participants Age range 9–11 years	EXP-2 groups Individual level randomization INT or CON groups	7 days of unsealed PED monitoring (self-reported by participants)	Internet-enabled adventure game designed to promote PA and healthy eating. To play the game, children were required to wear PEDs to record their real-life PA. Parents uploaded children's steps, which were converted into 'energy units' needed to play the game.	Baseline and posttest (4-week)	Small increase in PA (<500) among INT group.
Zizzi et al. (2006)	United States 165 participants Age range 14–17 years	QEXP-2 groups School level allocation. goal-setting INT group and CON group	7 days of unsealed PED monitoring	School-based INT (3-week). Participants in the INT group set daily step goals and were given one health-related handout each week for the 3-week intervention. Participants in the CON group were given PEDs and reported their step counts weekly.	Baseline and posttest (3-week)	No differences between groups. PA did not increase from baseline.
Goldfield et al. (2006)	Canada 30 overweight or obese participants Mean age 10 (±.9) and 10.7 (±1.4) years	EXP-2 groups Individual level randomization CON open-loop feedback or INT open-loop feedback plus reinforcement CON open-loop feedback or INT open-loop feedback plus reinforcement	7 days of unsealed PED monitoring and PA questionnaire	Children in the INT were provided with PED feedback on their PA levels. The PA accumulated was rewarded with access to television. Children in the CON group were required to wear PEDs, but had free access to televisions, independent of PA accumulated.	Baseline, weeks 1–2, weeks 3–5 and weeks 6–8	Significant group-by-time interaction effect. INT increased PA counts and self-reported PA more than CON.
Oliver et al. (2006)	New Zealand 78 participants Age range 8–10 years	No CON group	At baseline 3 days of sealed PED monitoring 4 weeks of unsealed PED monitoring during INT	Elementary school PA integration program (4-week). All disciplines were linked by a common topic of conducting a 'virtual' walk around New Zealand. Students wore unsealed PEDs everyday of the 4-week intervention.	Baseline and during 4-week INT	Significant increase in PA for participants classified as low-active at baseline. No difference for participants classified as active.
Berry et al. (2007)	United States 80 overweight participants Mean age 11.9 (±2.4) years	EXP-2 groups Family level randomization INT or CON groups	Unsealed PED monitoring—number of days not reported	Family-based intervention for obese parents and overweight children (6 months). Parents in the INT group participated in nutrition and exercise sessions. Parents and children in both INT and CON groups were provided with PEDs and walking log books. Children in both the INT and CON groups participated in 24 weeks of nutrition education (12 weeks) and exercise sessions (12 weeks).	Baseline, 3 months and 6 months	Participants in both the INT and CON groups increased their PA from baseline. No between group differences.
Butcher et al. (2007)	United Kingdom 177 participants Mean age 9.1 (±1.1) years	EXP-3 groups School level randomization CON group, PED feedback group and PED feedback plus	5 days of unsealed PED monitoring	PED feedback group wore unsealed PEDs for 5 days and were encouraged to look at PEDs and attempt to increase their steps counts the next day. The PED feedback plus information group wore unsealed PEDs and also received information and support from teachers on how to increase their step counts. CON group wore sealed PEDs for the 5-day	PA assessed over 5-day study (no baseline)	Participants in the PED feedback plus information accumulated significantly more PA than PED feedback only and CON groups.

(continued on next page)

Table 1 (*continued*)

Study	Sample	Design	PA measure	Description of pedometer intervention component	Assessment	Results
		information group		study period.		
Horne et al. (2009)	United Kingdom 100 participants Age range 9–11 years	EXP-2 groups School level randomization INT or CON groups	8 days of sealed PED monitoring	School-based INT (12-week) involving peer modeling, rewards and PED-feedback intervention designed to increase PA based on the Food Dude healthy eating program. Participants were provided with individualized step-targets based on their baseline step counts.	Baseline, mid-intervention and posttest (12-week)	Girls and boys in the INT group significantly increased their PA from baseline. At posttest girls accumulated significantly more PA than girls in the CON group. There were no differences between boys at posttest.
Rodearmel et al. (2007)	United States 218 overweight or at risk of overweight children Age range 7–14 years	EXP-2 groups Family level randomization INT or CON groups	2 weeks of unsealed PED monitoring	INT group participated in family-based intervention (6-month) which included face-to-face sessions focusing on strategies to increase PA. Families provided with PEDs and encouraged to increase and maintain their PA by 2000 steps/day above their baseline counts. Participants in the CON group were provided with PEDs and asked to monitor their PA behaviors over the study period.	Baseline and every week for 24 weeks	INT participants reported significantly more steps/day than CON participants. Differences were maintained over the study period.
Lubans and Morgan (2008)	Australia 116 participants Mean age 14.2 (±.5) years	QEXP-2 groups School year level allocation INT or CON groups	4 days of sealed PED monitoring	School-based INT (8-week) promoting lifestyle and lifetime PA. PED-based goal-setting and self-monitoring incorporated into a extra-curricular school sport program focusing on health-related fitness activities.	Baseline and posttest (8-week)	INT participants classified as low-active at baseline significantly increased PA at posttest. Significant difference between CON and INT for participants classified as low-active at baseline. INT did not impact on PA levels of participants classified as active at baseline.
Tsiros et al. (2008)	Australia 47 overweight and obese adolescents Age range 12–18 years	EXP-2 groups Individual level randomization INT or CON groups	7 days of unsealed PED monitoring	INT group participated in 10 behavioral and cognitive therapy sessions. Participants were provided with PEDs and intervention sessions addressed self-monitoring and goal-setting behaviors. CON group received no intervention.	Baseline, mid-intervention (10-week), and posttest (20-week)	No significant differences between groups at posttest. PA did not increase from baseline in the INT group.
Lubans et al. (2009)	Australia 124 participants Mean age 14.1 (±.8) years	EXP-2 groups School level randomization INT or CON groups	5 days of sealed PED monitoring including 1 weekend day	Multi-component, school-based INT (6-month) that included health-related fitness activities, PEDs for self-monitoring and social support from parents and emails.	Baseline and posttest (6-month)	Boys and girls in the INT group classified as low-active at baseline significantly increased PA at posttest. INT did not impact on PA levels of participants classified as active at baseline.

Abbreviations: EXP = experimental study design, QEXP = quasi-experimental study design, CON = control, INT = intervention, PA = physical activity, PED = pedometer.

suggested that step goals should be personalized according to baseline values, specific health goals and sustainability (Tudor-Locke and Corbin, 2002). The disadvantage of using pedometers to prescribe physical activity targets for youth is that they do not provide information about physical activity intensity while recommendations for physical activity are usually based on time and intensity. While pedometer output correlates strongly with different accelerometers which do collect time and intensity information (Tudor-Locke et al., 2002), the relationship between step counts and doubly labelled water is less convincing (Ramirez-Marrero et al., 2005).

The activity patterns of youth have been characterized as intermittent or sporadic, displaying brief bursts of intense movement interspersed with bouts of light and sedentary activity (Welk et al., 2000). Trying to capture random spurts of intensity using accelerometers, for example, is challenging as the epochs (that is, sample intervals) necessary are shorter than is conventionally used or feasible for longer term monitoring given limitations of current instrumentation (McClain et al., 2008). Although it is correct that pedometers are insensitive to non-ambulatory activities such as cycling and should not be worn while swimming, we know from the adult literature that these types of activities are particularly salient (that is, easily recalled). Further, although it may be important to consider adjusting steps taken for such activities by a simple conversion factor, it seems to be important only for individual results and not for population estimates (Miller et al., 2006). Given the more common features of young people's movement behaviors, and the current public health emphasis on accumulation of daily physical activity (National Association of Physical Education and Sports, 2004), it follows that a cumulative record of steps taken at the end of the day is an appropriate indicator to monitor in youth. Finally, a recent review of pedometer-determined free-living physical activity in young populations documents 31 studies published since 1999 that provides normative data for comparison purposes, further supporting the usefulness of these types of data in youth (Tudor-Locke et al., in press-a).

Two recent meta-analyses have examined the impact of pedometers on physical activity and health in adults (Bravata et al., 2007; Richardson et al., 2008). Pedometers were found to be associated with an increase in physical activity of approximately 2000 steps/day and decreases in BMI and blood pressure. While pedometers appear to have an important role to play in the promotion of lifestyle activity among adults, less is known regarding their impact on behavior among youth (i.e., children and adolescents). The primary aim of this review was to identify the effectiveness of pedometers in promoting physical activity among youth. Secondary aims were to assess the quality of existing studies and examine the different ways that pedometers have been used to promote physical activity among youth.

Methods

Identification of studies

A systematic search of studies using pedometers to increase physical activity in young people was conducted using six electronic databases (Pubmed, Psychinfo, SCOPUS, Ovid Medline, Sportdiscus, and Embase) from the year of their inception up to and including December 2008. The search was conducted on the 21st of January 2009. Individualized search strategies for the different databases included combinations of the following key words 'physical activity', 'walking', 'child', 'adolescent', 'young people', 'intervention', 'promotion', 'evaluation' and 'pedometer'. The review was conducted in three stages. In the first stage of the review, articles were included or excluded based on their title or abstract. In the second stage, full-text articles were retrieved and assessed for relevance. In the final stage, the references of all full-text articles were searched for additional articles. Only articles published (or in press) in refereed journals were considered for the review. Conference proceedings and abstracts were not included.

Criteria for inclusion/exclusion

Two of the authors (DRL and PJM) independently assessed the eligibility of the studies for inclusion according to the following criteria: (i) child and adolescent participants (aged 5–18 years) (ii) quantitative assessment of physical activity as a dependent variable, (iii) study design used an experimental or quasi-experimental design, (iv) study included pedometer-based strategy to promote physical activity, and (v) published in English. The Quality of Reporting of Meta-analyses statement (QUOROM) (Moher et al., 1999) was consulted and provided the structure for this review. The flow of studies through the review process is reported in Fig. 1.

Criteria for assessment of study quality

Two of the three authors (DRL and PJM) assessed the quality of the studies that met the inclusion criteria. A formal quality score for each study was completed on a 10-point scale by assigning a value of 1 (yes) or 0 (no or unclear) to each of the following questions listed: (i) Were the groups comparable at baseline on key characteristics (yes, if stratified baseline characteristics were reported and groups were similar)? (ii) Was the process of randomization clearly described and adequately carried out (envelope or algorithm)? (iii) Was the unit of analysis individual or did the analysis account for clustering of effects? (iv) Was an objective measure of physical activity used? (v) Did the authors provide a CONSORT flow diagram and did at least 80% of participants complete follow-up assessments? (vi) Did the study include a follow-up assessment of at least 6 months? (vii) Were the assessors blinded to group allocation at assessment periods? (viii) Did the study report a power calculation and was the study adequately powered to detect changes in physical activity? (ix) Was the physical activity outcome measure controlled for baseline activity level? (x) Was intention-to-treat analysis used? Studies that scored 0–2 were regarded as low quality studies, studies that scored 3–6 were classified as medium quality and those that scored 7–10 high quality. These criteria were adapted from the Consolidated Standards of Reporting Trials (CONSORT) statement (Moher et al., 2001).

Table 2
Pedometer study quality checklist with quality scores assigned

Studies	1) Were the groups comparable at baseline on key characteristics (yes, if stratified baseline characteristics were reported and groups were similar)?	2) Was the process of randomization clearly described and adequately carried out (envelope or algorithm)?	3) Was the unit of analysis individual or did the analysis account for clustering of effects?	4) Was an objective measure of physical activity used?	5) Did the authors provide a CONSORT flow diagram and did at least 80% of participants complete follow-up assessments?	6) Did the study include a follow-up assessment of at least 6 months?	7) Were the assessors blinded to group allocation at assessment periods?	8) Did the study report a power calculation and was the study adequately powered to detect changes in physical activity?	9) Was the physical activity outcome measure controlled for baseline activity level?	10) Was intention-to-treat analysis used?	Score/10
Goldfield et al. (2000)	Yes	No	Yes	Yes	No	No	No	No	No	No	3
Schofield et al. (2005)	No	No	No	Yes	No	No	No	No	Yes	No	2
Lieberman et al. (2006)	No	No	Yes	Yes	No	No	No	No	No	No	2
Southard and Southard (2006)	No	No	Yes	Yes	No	No	No	No	No	No	2
Zizzi et al. (2006)	No	No	No	Yes	No	No	No	No	Yes	No	2
Goldfield et al. (2006)	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	8
Oliver et al. (2006)	No	No	Yes	Yes	No	No	No	No	Yes	No	3
Berry et al. (2007)	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	No	6
Butcher et al. (2007)	Yes	No	No	Yes	No	No	No	No	No	No	2
Horne et al. (2009)	Yes	No	No	Yes	No	No	No	No	Yes	No	3
Rodearmel et al. (2007)	Yes	No	No	Yes	No	Yes	No	No	Yes	Yes	5
Lubans and Morgan (2008)	Yes	No	No	Yes	No	No	No	Yes	Yes	No	4
Tsiros et al. (2008)	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	7
Lubans et al. (2009)	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	7

Results

Overview of studies

A total of 842 potentially relevant studies were identified from our database searches. From this number, 14 studies satisfied the inclusion criteria and were included in this review (Table 1). The flow of studies through the review process and the reasons for exclusion are reported in Fig. 1, however it is possible that studies were excluded for multiple and different reasons. Six studies were conducted in schools (Butcher et al., 2007; Horne et al., 2009; Lubans and Morgan, 2008; Oliver et al., 2006; Schofield et al., 2005; Zizzi et al., 2006), two were community-based (Goldfield et al., 2006; Southard and Southard, 2006), and one was delivered in a clinical setting (Tsiros et al., 2008). Two interventions were family-based and included parents and children (Berry et al., 2007; Rodearmel et al., 2007), one study assessed changes in physical activity among blind children at an activity camp (Lieberman et al., 2006) and another study examined physical activity behavior in a laboratory setting (Goldfield et al., 2000). Seven studies involved children, aged 8–11 years (Butcher et al., 2007; Goldfield et al., 2000; Goldfield et al., 2006; Horne et al., 2009; Lieberman et al., 2006; Oliver et al., 2006; Southard and Southard, 2006), five studies included adolescent participants, aged 14–17 years (Lubans and Morgan, 2008; Lubans et al., 2009; Schofield et al., 2005; Tsiros et al., 2008; Zizzi et al., 2006) and two studies included children and adolescents in family-based interventions (Berry et al., 2007; Rodearmel et al., 2007). The shortest study period was 20 min and the longest assessment period was 6 months (Berry et al., 2007; Lubans et al., 2009; Rodearmel et al., 2007). The sample sizes for the studies ranged from 22 (Lieberman et al., 2006) to 218 (Rodearmel et al., 2007).

Overview of study quality

There was 96% agreement between authors on the study assessment criteria and full consensus was achieved after discussion. Study quality criteria and results are reported in Table 2. Three studies were identified as high quality (Goldfield et al., 2006; Lubans et al., 2009; Tsiros et al., 2008), six studies were identified as medium quality (Berry et al., 2007; Goldfield et al., 2000; Lubans and Morgan, 2008; Oliver et al., 2006; Rodearmel et al., 2007) and the remaining five studies were classified as low quality (Butcher et al., 2007; Lieberman et al., 2006; Schofield et al., 2005; Zizzi et al., 2006).

Open-loop feedback studies

In a laboratory setting, Goldfield et al. (2000) investigated whether making access to video games or movies dependent on physical activity would increase overall physical activity. The authors found that children who were given physical activity targets spent more time in moderate-to-vigorous physical activity, and that those required to take more steps were more physically active, compared to children whose access to sedentary activities was non-contingent. In a study building upon their earlier work, Goldfield et al. (2006) compared the effects of an open-loop feedback system that rewarded overweight children who had accumulated step counts with television access. Children in the open-loop feedback group demonstrated significantly greater increases in daily pedometer-determined physical activity, from 247 activity counts/day at baseline to 408 activity counts/day) over the study period (8 weeks). Physical activity counts among children in the control group remained stable over the study period.

Southard and Southard (2006) evaluated the effects of an Internet-enabled adventure game (*MetaKenkoh*) designed to promote physical activity and healthy eating in children 9–11 years of age. In order to play the game, children were required to wear pedometers to record their real life physical activity. Parents then entered their children's step counts to an associated Internet site. Step counts were converted to energy units, which were necessary to play the game. Underweight and normal weight children in the intervention group showed an increase of approximately 400 steps/day from baseline. This increase was approximately 1000 steps/day higher than children in the control group, who decreased from baseline. Children in the intervention and control groups who were overweight or at risk of overweight showed a slight increase in physical activity (approximately 400–500 steps/day) over the 4-week study period.

Self-monitoring and goal-setting studies

Ten studies used pedometers for self-monitoring and goal-setting. Eight of the ten studies resulted in increases in physical activity. The pedometer goal-setting and behavior tracking intervention evaluated by Zizzi et al. (2006) resulted in modest (from a baseline average of approximately 8900 steps/day to 9200 steps/day after 4 weeks) and mostly non-significant (only 1 in 4 schools studied reached significance) results in a study of 165 high school students aged 14–17 years. Study participants were asked to set daily step goals after wearing their pedometers at baseline, but participants were not given feedback as to whether or not they achieved their targets. In the *Girls Stepping out Program* (GSOP) (Schofield et al., 2005), only individuals in the step-based intervention group significantly increased their step counts from baseline (by approximately 2700 steps/day). Participants set their goals on their individual baseline data and were encouraged to increase their activity by a daily average of 1000–2000 steps for each week, until they reached 10,000 steps/day.

The *Learning to Enjoy Activity with Friends* (LEAF) (Lubans and Morgan, 2008) and *Program X* (Lubans et al., 2009) interventions were multi-component programs that combined pedometer goal-setting and behavior tracking with health-related fitness activities to promote lifestyle and lifetime physical activities. Both studies resulted in significant increases in physical activity among participants classified as low-active at baseline, but not on participants classified as active. Detail describing the type of goals set in both studies was not clearly articulated in the Methods sections. The LEAF intervention was evaluated over a 2-month period, while *Program X* involved additional behavior change mechanisms and included a 6-month follow-up. Parent newsletters, social support via emails and a summary lecture were included in the *Program X* intervention to support longer-term behavior change.

Two studies examined physical activity self-monitoring among children in primary schools. The *Fit n' Fun Dudes* intervention (Horne et al., 2009) was a peer modeling, rewards and pedometer feedback intervention for elementary school children aged 9–11 years. Individualized step targets were determined by participants' baseline physical activity levels. Participants were encouraged to increase their step counts by 1500 steps/day. The intervention group actually increased their physical activity from baseline by approximately 2700–3800 steps/day, which was significantly higher than those in the control group. Butcher et al. (2007)) examined whether step count feedback alone or combined with physical activity information could increase the number of steps taken in one school week by 177 elementary school children (mean age = 9.1 years). The authors reported that participants in the feedback plus information group were significantly more active (reported as approximately 17 steps/minute) over the study period compared with the step count feedback only group (approximately 14 steps/minute) and a control group (approximately 12 steps/minute).

Tsiros et al. (2008) included pedometers for physical activity self-monitoring in a cognitive behavioral therapy intervention for overweight and obese adolescents. Adolescents participated in 10 cognitive behavioral therapy sessions and each participant was provided with a pedometer to promote physical activity. However, the study does not describe how the pedometer was used to increase physical activity. Step counts did not increase over the study period and there were no differences between participants in the two treatment conditions.

Two family-based interventions used pedometers for self-monitoring and goal-setting (Berry et al., 2007; Rodearmel et al., 2007). In the *America on the Move* (AOM) study, 298 families were randomized to the AOM intervention or a control group (Rodearmel et al., 2007). After establishing baseline activity level, each AOM family participant was instructed to increase their daily activity by 2000 steps/day above their baseline. Children in the AOM intervention increased their step counts from 9265 at baseline to over 10,500 throughout the 6-month period. Berry et al. (2007) evaluated an intervention for multiethnic obese parents with overweight children. Families were randomized to the *Nutrition and Exercise Education Program* (NEEP) or a control group. Both groups were provided with pedometers and logbooks for self-monitoring and encouraged to monitor their activity. Children in the intervention and control groups both increased (approx. 3000 steps/day) their physical activity from baseline and there were no differences between groups at the 6-month posttest.

Lieberman et al. (2006) used talking pedometers to promote physical activity among blind children at a 1-week summer activity camp. Details describing how the pedometers were used are not provided, however, the authors reported that step counts were higher during the camp than at baseline. Step counts increased from 9686 to 14,663 steps/day for girls and 9770 to 16,321 steps/day for boys.

Physical activity curriculum integration studies

Oliver et al. (2006) evaluated a physical activity integration curriculum program for elementary school children (aged 8–10 years). Pedometers were used as motivational, educational and measurement tools for physical activity. All school subjects (e.g., English, Mathematics, Science) in a 4-week unit of school work were linked by a common topic of conducting a “virtual” walk around New Zealand. The study reported a significant increase in physical activity from baseline to posttest (approximately 2000–4000 steps/day) for participants classified as low-active at baseline, but not for those classified as sufficiently active (i.e., ≥15,000 steps/day).

Discussion

Effectiveness of pedometers to increase physical activity

The primary aim of this review was to identify the effectiveness of pedometers in promoting physical activity among youth. Twelve of the 14 studies included in this review resulted in significant increases in physical activity. There was considerable variation in the magnitude of the intervention effects, which may be attributed to differences in the study participants (e.g. child or adolescent, obese or healthy weight), assessment methods (e.g. sealed or unsealed pedometers) and study design (e.g. 1-week intervention versus 6-month intervention).

It appears that pedometer feedback alone, through awareness of daily step counts, is not enough to increase physical activity behavior among youth. For example, in the study by Butcher et al. (2007), the step count feedback plus information group achieved significantly more steps at 1-week posttest, than the step feedback only and control groups, whose steps values remained relatively stable over the study period. Additional behavior change strategies (e.g. goal-setting and self-monitoring) combined with social support, for example, may be necessary to increase activity behavior. Although based on few studies, the findings from this review confirm those of the meta-analysis completed by Bravata et al. (2007), who concluded that setting step goals and using a physical activity step diary were the key motivational factors for increasing physical activity.

In the current review, the only goal-setting and self-monitoring study that did not result in increased physical activity was the study by Zizzi et al. (2006). The low methodological quality of this study may have contributed to the discrepancy in the effectiveness of this study. Furthermore, participants in the intervention group were not given feedback on whether or not they met their step goals each week. This is a limitation of the intervention, as feedback regarding step targets appears to be an important component of pedometer interventions (Butcher et al., 2007; Lubans and Morgan, 2008, Lubans et al., 2009; Schofield et al., 2005). Although the studies included in this review cannot confirm our hypothesis, it is possible that goal-setting with pedometers is not as socially acceptable for older adolescents, or considered as novel, as may be the case with younger children. To help answer these questions, future studies should explore children and adolescents' attitudes toward pedometer monitoring to determine if age, gender and demographic differences exist.

Four of the studies (Lubans and Morgan, 2008; Lubans et al., 2009; Oliver et al., 2006; Schofield et al., 2005) included in this review evaluated the impact of an intervention on physical activity behavior among study participants who were classified as 'low-active' at baseline. All four studies demonstrated increases in physical activity in this subgroup. The interventions had less or no impact on sufficiently active individuals (Lubans and Morgan, 2008; Lubans et al., 2009; Oliver et al., 2006), suggesting that goal-setting with pedometers is an effective strategy for increasing activity among less active youth. It appears that youth accumulating approximately ≥13,000–15,000 steps/day do not respond to goal-setting targets and activity monitoring with pedometers.

Pedometer strategies to promote physical activity

This review identified three major strategies to promote physical activity among youth using pedometers: (i) open-loop feedback linked to access to sedentary activities, (ii) self-monitoring and goal setting, and (iii) physical activity integration across curriculum areas. One study used a talking pedometer to increase physical activity among blind children (Lieberman et al., 2006). However, the authors did not provide sufficient detail as to how the pedometer was used and as the children were attending an activity camp, the increases in physical activity may not be attributable to the talking pedometer.

Three studies used open-loop feedback to encourage children to increase their physical activity and all studies resulted in immediate increases in physical activity. In these studies, participants were rewarded with access to electronic games based on the amount of physical activity they accumulated. While there appears to be some evidence for the short-term effectiveness of this approach, as the longest of the three studies was only 8 weeks in duration, we cannot conclude whether this strategy is an effective approach to promoting sustainable behavior change. A recent systematic review of physical activity interventions among youth indicated that the lack of a long-term follow-up was a common limitation among studies (Van Sluijs et al., 2007).

Quality of pedometer-based interventions

The relationship between study quality and observed effect was not clear as only three studies were regarded as high quality and there was considerable variety in study design and implementation. Most of the studies included in the review failed to cite a power calculation to indicate an adequate sample size to detect changes in physical activity. Few studies included an intention-to-treat analysis or controlled for the clustering of effects within groups (e.g. schools or families). Pedometers were used by almost all of the studies to assess physical activity behavior change. It has been suggested that using pedometers as both an intervention strategy to increase physical activity and as a tool to measure changes in physical activity may be a study limitation (Bravata et al., 2007). However, there is a lack of evidence supporting the existence of reactivity to pedometer use among youth (Ozdoba et al., 2004; Tudor-Locke et al., in press-b; Vincent and Pangrazi, 2002).

While reactivity has been suggested as an explanation for an increase in steps counts in a control condition (e.g. Southard and Southard, 2006), there is little evidence to support this speculation. If there is some reactivity that has not been captured in these studies, it would affect both the intervention and control groups equally, making any measurement differences redundant.

Finally, if the alternative measure is to be an accelerometer, it still is a body worn technology which does not circumvent the fact that individuals are completely aware of the monitor's purpose. If the alternative is a self-report measure, again this approach may lead to a potential reporting bias. In the end, it appears appropriate to evaluate the effect of pedometer interventions on physical activity behavior using pedometers.

To improve the quality of studies reporting the effects of pedometer use on physical activity behavior, we suggest that future studies consult the CONSORT Statement (Moher et al., 2001). While the CONSORT was designed as a guide for randomized controlled trials, researchers are advised to use this statement when designing and reporting interventions. The CONSORT statement provides important information regarding the study objectives and intended outcomes, intervention design, allocation and blinding procedures, statistical methods employed and flow of participants through the study process.

Study limitations

Limitations of our review should be noted. First, it is possible that studies satisfied our assessment criteria but did not report the necessary information. Second, there is likely to be publication bias in this review because studies that find a positive result are more likely to be published than studies that fail to find an intervention effect. Furthermore, there is potential bias in the selection of studies because we were able to include additional studies that we were aware of, but were not yet available through an electronic literature search. Our strategy was limited to published studies identified through the selected search engines. As more studies continue to be published, it will be important to reconsider and refine these findings.

Future research and implications

Future research should explore the long-term effectiveness of pedometers on physical activity behavior change. The longest study period included in this review was 6 months and longer term studies (>12 months) are needed. More studies are needed to explore the potential of physical activity curriculum integration programs in primary and secondary schools. The crowded school curriculum has pressured reductions in the amount of time available for physical education (Morgan and Hansen, 2007). Physical activity integration into other key learning areas (e.g., English, mathematics) offers an opportunity for the promotion of physical activity throughout the school day. While pedometers have emerged as motivational tools for the promotion of lifestyle physical activity, pedometers may also be used to encourage higher intensity physical activity by providing young people with time-based step targets (Scruggs, 2007). For example, future studies might evaluate the effect of physical education classes that encourage students to accumulate a certain number of steps in a period of time. This strategy may help to improve cardiorespiratory fitness and provide educators and researchers with another use for pedometers in the school setting.

Conclusions

In general, pedometer-based interventions appear to be more effective with low active adolescents, whereas in children the effect seems to be observed in all participants. This observation must be tempered, however, by the fact that there are few studies of both children and adolescents at this time to make more solid conclusions. Due to the small number of studies and the inconsistency in study design and quality, it is difficult to establish guidelines regarding the appropriate use of pedometers to promote physical activity levels in youth. Since there are so few studies at this time, yet their results are generally positive in terms of impacting physical activity, there is ample need and opportunity to contribute to the knowledge base of youth pedometry.

Conflict of interest statement

The authors have no conflict of interest to declare.

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