

A Systematic Review of Studies using Pedometers to Promote Physical Activity  
among Youth

David R. Lubans<sup>1\*</sup>, Philip J. Morgan<sup>1</sup>, and Catrine Tudor-Locke<sup>2</sup>

\* Corresponding author

David Lubans, DPhil

University of Newcastle

School of Education

Callaghan Campus

NSW 2308

Australia

Email: [David.Lubans@newcastle.edu.au](mailto:David.Lubans@newcastle.edu.au)

Telephone: +61 2 49212049

Fax: +61 2 49217407

<sup>1</sup>School of Education, The University of Newcastle, Callaghan Campus, AUSTRALIA

<sup>2</sup>Walking Behavior Laboratory, Pennington Biomedical Research Center, Baton Rouge, U.S.

Abstract word count: 200  
Manuscript word count: 3,551  
Tables: 2  
Figures: 1

**Abstract**

*Background:* While pedometers 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 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 fourteen 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.

## 1    **Introduction**

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

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

21           Although recommendations for physical activity have traditionally been time  
22    and intensity-based (i.e. 30 minutes/day of moderate-to-vigorous physical activity at  
23    least five times a week), in response to the ubiquity of pedometers, daily targets of  
24    10,000 steps/day for adults have emerged. However, Tudor-Locke and Myers (Tudor-  
25    Locke and Myers, 2001) have suggested that 10,000 steps/day is unrealistically high

1 for low-active or sedentary adults and may contribute to low program adherence. The  
2 step recommendations for children and adolescents are equally problematic. While the  
3 President's Council on Physical Fitness and Sports recommends 13,000 steps/day for  
4 boys and 11,000 steps for girls (President's Council on Physical Fitness & Sports,  
5 2002), recent studies examining the relationship between step-counts and body mass  
6 index (BMI) have suggested that the step targets should be as high as 12,000 for girls  
7 and 15,000 for boys (Tudor-Locke, et al., 2004). Having a standard step target may  
8 not be necessary and it has been suggested that step goals should be personalized  
9 according to baseline values, specific health goals and sustainability (Tudor-Locke  
10 and Corbin, 2002). The disadvantage of using pedometers to prescribe physical  
11 activity targets for youth is that they do not provide information about physical  
12 activity intensity while recommendations for physical activity are usually based on  
13 time and intensity. While pedometer output correlates strongly with different  
14 accelerometers which do collect time and intensity information (Tudor-Locke, et al.,  
15 2002), the relationship between step counts and the doubly labelled water is less  
16 convincing (Ramirez-Marrero, et al., 2005).

17       The activity patterns of youth have been characterized as intermittent or  
18 sporadic, displaying brief bursts of intense movement interspersed with bouts of light  
19 and sedentary activity (Welk, et al., 2000). Trying to capture random spurts of  
20 intensity using accelerometry technology, for example, is challenging since the  
21 epochs (that is, sample intervals) necessary are shorter than is conventionally used or  
22 feasible for longer term monitoring given limitations of current instrumentation  
23 (McClain, et al., 2008). Although it is correct that pedometers do not detect non-  
24 ambulatory activities such as cycling and swimming (in this latter activity pedometer  
25 should not be worn), we know from 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 the accumulation of daily physical activity (National Association of Physical Education and Sports, 2004, U.S. Department of Health & Human Services, 1996), 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 2,000 steps per 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 21<sup>st</sup> 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 Figure 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).

## **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 Figure 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 clinic 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 minutes 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*



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

14 Southard and Southard (Southard and Southard, 2006) evaluated the effects of  
15 an Internet-enabled adventure game (*MetaKenkoh*) designed to promote physical  
16 activity and healthy eating in children 9-11 years of age. In order to play the game,  
17 children were required to wear pedometers to record their real life physical activity.  
18 Parents then entered their children's step counts to an associated Internet site. Step  
19 counts were converted to energy units, which were necessary to play the game.  
20 Underweight and normal weight children in the intervention group showed an  
21 increase of approximately 400 steps/day from baseline. This increase was  
22 approximately 1,000 steps/day higher than children in the control group, who  
23 decreased from baseline. Children in the intervention and control groups who were  
24 overweight or at risk of overweight showed a slight increase in physical activity  
25 (approximately 400-500 steps/day) over the 4-week study period.

### 1 *Self-monitoring and goal setting*

2       Ten studies used pedometers for self-monitoring and goal setting. Eight of the  
3       ten studies resulted in increases in physical activity. The intervention evaluated by  
4       Zizzi and colleagues (2006) resulted in modest (from a baseline average of  
5       approximately 8,900 steps/day to 9,200 steps/day after four weeks) and mostly non-  
6       significant (only 1 in 4 schools studied reached significance) results in a study of 165  
7       high school students aged 14-17 years. Study participants were asked to set daily step  
8       goals after wearing their pedometers at baseline, but participants were not given  
9       feedback as to whether or not they achieved their targets. In the *Girls Stepping out*  
10      *Program* (GSOP) (Schofield, et al., 2005), only individuals in the step-based  
11      intervention group significantly increased their step counts from baseline (by  
12      approximately 2,700 steps/day). Participants set their goals on their individual  
13      baseline data and were encouraged to increase their activity by a daily average of 1-  
14      2000 steps for each week, until they reached 10,000 steps/day.

15      The *Learning to Enjoy Activity with Friends* (LEAF) (Lubans and Morgan,  
16      2008) and *Program X* (Lubans, et al., 2009) interventions were multi-component  
17      programs that combined pedometer goal setting and behavior tracking with health-  
18      related fitness activities to promote lifestyle and lifetime physical activities. Both  
19      studies resulted in significant increases in physical activity among participants  
20      classified as low-active at baseline, but not on participants classified as active. Detail  
21      describing the type of goals set in both studies is not clearly articulated in the methods  
22      sections. The LEAF intervention was evaluated over a two-month period, while  
23      *Program X* involved additional behavior change mechanisms and included a six  
24      month follow-up. Parent newsletters, social support via emails and a summary lecture  
25      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 1,500 steps per day. The intervention group actually increased their physical activity from baseline by approximately 2,700- 3,800 steps/day, which was significantly higher than those in the control group. Butcher and colleagues (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 and colleagues (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 2,000 steps/day above their baseline. Children in the AOM intervention increased their step counts from 9,265 at baseline to over 10,500 over 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. 3,000 steps/day) their physical activity from baseline and there were no differences between groups at the 6-month posttest.

Lieberman and colleagues (2006) used talking pedometers to promote physical activity among blind children at a one-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 9,686 to 14,663 steps/day for girls and 9,770 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 2,000-4,000 steps/day) for participants classified as low-active at baseline, but not for those classified as sufficiently active (i.e.,  $\geq 15,000$  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 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 and colleagues (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 and colleagues (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 and colleagues (Zizzi, et al., 2006). The low 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 baseline low-active participants. 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 more sedentary youth. It appears that youth accumulating approximately  $\geq 13,000$ -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

1 attending an activity camp, the increases in physical activity may not be attributable to  
2 the talking pedometer.

3 Three studies used open-loop feedback to encourage children to increase their  
4 physical activity and all studies resulted in immediate increases in physical activity. In  
5 these studies participants were rewarded with access to electronic games based on the  
6 amount of physical activity they accumulated. While there appears to be some  
7 evidence for the short-term effectiveness of this approach, as the longer of the three  
8 studies was only 8-weeks in duration, we cannot conclude whether this strategy is an  
9 effective approach to promoting sustainable behavior change. A recent systematic  
10 review of physical activity interventions among youth indicated that the lack of a  
11 long-term follow-up was a common limitation among studies (Van Sluijs, et al.,  
12 2007).

### 13 *Quality of Pedometer-based Interventions*

14 The relationship between study quality and observed effect was not clear  
15 as only three studies were regarded as high quality and there was considerable  
16 variety in study design and implementation. Most of the studies included in the  
17 review failed to cite a power calculation to indicate an adequate sample size to  
18 detect changes in physical activity. Few studies included an intention-to-treatment  
19 analysis and controlled for the clustering of effects within groups (e.g. schools or  
20 families). Pedometers were used by almost all of the studies to assess physical  
21 activity behavior change. It has been suggested that using pedometers as both an  
22 intervention strategy to increase physical activity and as a tool to measure changes  
23 in physical activity may be a study limitation (Bravata, et al., 2007). However,  
24 there is a lack of evidence supporting the existence of reactivity to pedometer use  
25 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 does not get around a potential reporting bias either. 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 cardio-respiratory 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

1     few studies of both children and adolescents at this time to make more solid  
2     conclusions. Due to the small number of studies and the inconsistency in study design  
3     and quality, it is difficult to establish guidelines regarding the appropriate use of  
4     pedometers to promote physical activity levels in youth. Since there are so few studies  
5     at this time, yet their results are generally positive in terms of impacting physical  
6     activity, there is ample need and opportunity to contribute to the knowledge base of  
7     youth pedometry.

8     *Conflict of interest statement*

9             The authors have no conflict of interest to declare.

10

1 **References**

- 2 Berry, D., Savoye, M., Melkus, G., Grey, M., 2007. An intervention for multiethnic  
3 obese parents and overweight children. *Appl Nurs Res.* 20, 63-71
- 4 Biddle, S., Gorely, T., Stensel, D., 2004. Health-enhancing physical activity and  
5 sedentary behaviour in children and adolescents. *J. Sports Sci.* 22, 679-701.
- 6 Bravata, D.M., Smith-Spangler, C., Sundaram, V., Gienger, A.L., Lin, N., Lewis, R.,  
7 Stave, C.D., Olkin, I., Sirard, J.R., 2007. Using pedometers to increase  
8 physical activity and improve health: A systematic review. *JAMA.* 298, 2296-  
9 3204.
- 10 Butcher, Z., Fairclough, S., Stratton, G., Richardson, D., 2007. The effect of feedback  
11 and information on children's pedometer step counts at school. *Pediatr Exerc*  
12 *Sci.* 19, 29-38.
- 13 Church, T.S., Earnest, C.P., Skinner, J.S., Blair, S.N., 2007. Effects of different doses  
14 of physical activity on cardiorespiratory fitness among sedentary, overweight  
15 or obese postmenopausal women with elevated blood pressure. *JAMA.* 297,  
16 2081-2091.
- 17 Dunn, A.L., Andersen, R.E., Jakicic, J.M., 1998. Lifestyle physical activity  
18 interventions: history, short- and long-term effects, and recommendations. *Am*  
19 *J Prev Med.* 15, 398-412.
- 20 Goldfield, G.S., Kalakanis, L.E., Ernst, M.M., Epstein, L.H., 2000. Open-loop  
21 feedback to increase physical activity in obese children. *Int J Obes* 24, 888-  
22 892.
- 23 Goldfield, G.S., Mallory, R., Parker, T., Cunningham, T., Legg, C., Lumb, A., Parker,  
24 K., Prud'homme, D., Gaboury, I., Adamo, K.B., 2006. Effects of open-loop

- 1 feedback on physical activity and television viewing in overweight and obese
- 2 children: A randomized, controlled trial. *Pediatrics*. 118, e157-e166.
- 3 Horne, P.J., Hardman, C.A., Lowe, C.F., Rowlands, A.V., 2009. Increasing children's
- 4 physical activity: A peer modelling, rewards and pedometer-based
- 5 intervention. *Eur J Clin Nutr*. 63, 191-198.
- 6 Lieberman, L.J., Stuart, M.E., Hand, K., Robinson, B., 2006. An investigation of the
- 7 motivational effects of talking pedometers among children with visual
- 8 impairments and deaf-blindness *J Vis Impair Blind*. 100, 726-736.
- 9 Lubans, D.R., Morgan, P.J., 2008. Evaluation of an extra-curricular school sport
- 10 program promoting lifestyle and lifetime activity. *J Sport Sci*. 26, 519-529.
- 11 Lubans, D.R., Morgan, P.J., Callister, R., Collins, C.E., 2009. Effects of integrating
- 12 pedometers, parental materials, and email support within an extracurricular
- 13 school sport intervention. *J Adolesc Health*. 44, 176-183.
- 14 McClain, J.J., Abraham, T.L., Brusseau, T.A., Jr., Tudor-Locke, C., 2008. Epoch
- 15 length and accelerometer outputs in children: comparison to direct
- 16 observation. *Med Sci Sports Exerc*. 40, 2080-2087.
- 17 Miller, R., Brown, W., Tudor-Locke, C., 2006. But what about swimming and
- 18 cycling? How to 'count' non-ambulatory activity when using pedometers to
- 19 assess physical activity. *J Phys Act Health*. 3, 257-266.
- 20 Moher, D., Cook, D.J., Eastwood, S., Olkin, S., Rennie, D., Stroup, D.F., 1999.
- 21 Improving the quality of reports of meta-analyses of randomised controlled
- 22 trials: the QUOROM statement. *Lancet*. 354, 1896-1900.
- 23 Moher, D., Schulz, K.F., Altman, D.G., 2001. The CONSORT Statement: Revised
- 24 recommendations for improving the quality of reports of parallel-group
- 25 randomized trials. *Ann Intern Med*. 134, 657-662.

- 1 Morgan, P.J., Hansen, V., 2007. Recommendations to improve primary school PE: the  
2 classroom teacher's perspective. *J Educ Res.* 101, 99-112.
- 3 National Association of Physical Education and Sports, 2004. Guidelines for  
4 Appropriate Physical Activity for Elementary School Children: Update 2004.  
5 National Association of Physical Education and Sports, Reston, VA.
- 6 Oliver, M., Schofield, G., McEvoy, E., 2006. An integrated curriculum approach to  
7 increasing habitual physical activity in children: A feasibility study. *J School*  
8 *Health.* 76, 74-79.
- 9 Ozdoba, R.S., Corbin, C.B., LeMasurier, G.C., 2004. Does reactivity exist in children  
10 when measuring activity levels with unsealed pedometers? *Pediatr Exerc Sci.*  
11 16, 158-166.
- 12 President's Council on Physical Fitness & Sports, 2002. The Presidential Active  
13 Lifestyle Award (PALA), Washington.
- 14 Ramirez-Marrero, F., Smith, B., Sherman, W., Kirby, T., 2005. Comparison of  
15 methods to estimate physical activity and energy expenditure in African  
16 American children. *Int J Sports Med.* 26, 363-371.
- 17 Richardson, C.R., Newton, T.L., Abraham, J.L., Sen, A., Jimbo, M., Swartz, A.M.,  
18 2008. A meta-analysis of pedometer-based walking interventions and weight  
19 loss. *Ann Fam Med.* 6, 69-77.
- 20 Rodearmel, S.J., Wyatt, H.R., Stroebele, N., Smith, S.M., Ogden, L.G., Hill, J.O.,  
21 2007. Small changes in dietary sugar and physical activity as an approach to  
22 preventing excessive weight gain: The America on the move family study  
23 *Pediatr.* 120, 869-879.

- 1 Schofield, L., Mummery, W.K., Schofield, G., 2005. Effects of a controlled  
2 pedometer-intervention trial for low-active adolescent girls. *Med Sci Sports*  
3 *Exerc.* 37, 1414-20.
- 4 Scruggs, P., 2007. Middle school physical education physical activity quantification:  
5 A pedometer steps/min guideline. *Res Q Exerc Sport.* 78, 284-292.
- 6 Southard, D.R., Southard, B.H., 2006. Promoting physical activity in children with  
7 MetaKenkoh. *Clin Invest Med.* 29, 293-297.
- 8 Tsiros, M.D., Sinn, N., Brennan, L., Coates, A.M., Walkley, J.W., Petkov, J., Howe,  
9 P.R.C., Buckley, J.D., 2008. Cognitive behavioral therapy improves diet and  
10 body composition in overweight and obese adolescents *Am J Clin Nutr.* 87,  
11 1134-1140
- 12 Tudor-Locke, C., Corbin, C.B., 2002. Taking steps toward increased physical activity:  
13 Using pedometers to measure and motivate. *President's Council on Physical*  
14 *Fitness and Sports.* 3, 1-8.
- 15 Tudor-Locke, C., McClain, J.J., Abraham, T.L., Sisson, S.B., Washington, T.L., in  
16 press-a. Expected values for pedometer-determined physical activity in youth.  
17 *Res Q Exerc Sport.*
- 18 Tudor-Locke, C., McClain, J.J., Abraham, T.L., Sisson, S.B., Washington, T.L., in  
19 press-b. Pedometry methods for assessing free-living youth. *Res Q Exerc*  
20 *Sport.*
- 21 Tudor-Locke, C., Myers, A.M., 2001. Methodological considerations for researchers  
22 and practitioners using pedometers to measure (ambulatory) activity. *Res Q*  
23 *Exerc Sport.* 72, 1-12.
- 24 Tudor-Locke, C., Pangrazi, R.P., Corbin, C.B., Rutherford, W.J., Vincent, S.D.,  
25 Raustorp, A., Tomson, L.M., Cuddihy, T.F., 2004. BMI-referenced standards

1 for recommended pedometer-determined steps/day in children. *Prev Med.* 38,  
2 857-64.

3 Tudor-Locke, C., Williams, J.E., Reis, J.P., Pluto, D., 2002. Utility of pedometers for  
4 assessing physical activity. *Sports Med.* 32, 795-808.

5 U.S. Department of Health & Human Services, 2000. *Healthy People 2010:*  
6 *Understanding and Improving Health* (2nd Ed.). U.S. Government Printing  
7 Office, Washington D.C.

8 U.S. Department of Health & Human Services, 1996. *Physical Activity and Health: A*  
9 *Report of the Surgeon General.* U.S. Department of Health and Human  
10 Services, Centers for Disease Control and Prevention, National Center for  
11 Chronic Disease Prevention and Health Promotion, Atlanta, GA.

12 Van Sluijs, E.M.F., McMinn, A.M., Griffin, S.J., 2007. Effectiveness of interventions  
13 to promote physical activity in children and adolescents: Systematic review of  
14 controlled trials. *BMJ.* doi:10.1136/bmj.39320.843947.BE.

15 Vincent, S.D., Pangrazi, R.P., 2002. Does reactivity exist in children when measuring  
16 activity levels with pedometers? *Pediatr Exerc Sci.* 14, 56-63.

17 Welk, G.J., Corbin, C.B., Dale, D., 2000. Measurement issues in the assessment of  
18 physical activity in children. *Res Q Exerc Sport.* 71, 59-73.

19 Zizzi, S., Vitullo, E., Rye, J.A., O'Hara Tompkins, N., Abildso, C., Fisher, B.,  
20 Bartlett, M., 2006. Impact of a three-week pedometer intervention on high  
21 school students' daily step counts and perceptions of physical activity. *Am J*  
22 *Health Educ.* 37, 35-40.

23

24

**Table 1: Studies that have used Pedometers to Promote Physical Activity among Youth**



**Table 2: Pedometer Study Quality Checklist with Quality Scores Assigned**

**Figure 1: Flow of Studies through the Review Process**