Miguel-Berges, María L. and Reilly, John J. and Moreno Aznar, Luis A. and Jiménez Pavón, David (2017) Associations between pedometer determined physical activity and adiposity in children and adolescents. Clinical Journal of Sport Medicine. ISSN 1536-3724 , http://dx.doi.org/10.1097/JSM.0000000000000419

Associations Between Pedometer-Determined Physical Activity and Adiposity in Children and Adolescents: Systematic Review

María L. Miguel-Berges, MSc, BsC,*† John J. Reilly, MD, PhD,‡ Luis A. Moreno Aznar, MD, PhD,*†§¶ and David Jiménez-Pavón, PhD*‖

Abstract

Objective: The present review sought to examine the evidence on the associations between pedometer-determined physical activity and adiposity. **Design:** Of 304 potentially eligible articles, 36 were included. A search for observational studies was carried out using Cochrane Library (CENTRAL), the OVID (MEDLINE, Embase, and PsycINFO), EBSCOhost (Sportdiscus), and PEDro database from their commenced to July 2015. Of 304 potentially eligible articles, 36 were included. **Results:** Most studies (30/36; 83%) were cross sectional and all used proxies for adiposity, such as body mass index (BMI) or BMI z-score as the outcome measure. Few studies (2/36; 6%) focused on preschool children. There was consistent evidence of negative associations between walking and adiposity; significant negative associations were observed in 72% (26/36) of studies overall. **Conclusions:** The present review supports the hypothesis that higher levels of walking are protective against child and adolescent obesity. However, prospective longitudinal studies are warranted; there is a need for more research on younger children and for more "dose-response" evidence.

Key Words: pedometers, physical activity, obesity

(*Clin J Sport Med* 2017;0:1–12)

INTRODUCTION

A high proportion of youth in Europe and the United States do not meet current physical activity (PA) guidelines, highlighting the importance of promoting a physically active lifestyle among youth, despite the increasing recognition of the health benefits associated with PA participation.[1] Physical activity levels play a determinant role in the onset and development of obesity as well as in the maintenance of overall health in youth.[2] The use of objective methods for measuring PA has been highlighted as necessary for a proper understanding of associations of PA with health-related parameters such as adiposity.[1]

Since pedometers were suggested for the first time in 1997 as a potential tool for monitoring daily or weekly PA in children,[2] several reviews have been focused on the utility of pedometers for measuring PA.[3–9] Pedometers have been used successfully in a variety of ways to promote PA among youth,[6] and the validity of pedometers has been studied in depth, raising this method as appropriate.[3,4,7–9] Moreover, Tudor-Locke et al[5] revised the evidence on the number of steps per day which should be recommended and concluded that this should range from approximately 12 000 to 16 000 and from 10 000 to 14 000 steps per weekday in boys and girls, respectively (on weekend days allowing for an average decrease of 2000 steps/d). Duncan et al[10] proposed a similar optimal step count cutoff point based on associations with body fat (16 000 and 13 000 steps/d for boys and girls, respectively).

In recent years, there has been an increased interest in objective monitoring of daily PA using simple and inexpensive methods; however, it is not clear whether pedometers could provide a suitably accurate estimate of PA to enable the detection of a significant association with adiposity or not. Jiménez-Pavón et al,[1] who reviewed the literature in 2008, found consistent evidence of negative associations between objectively measured physical activity and adiposity, although few studies used pedometers at that time. More recent reviews on associations between objectively measured PA, particularly moderate-to-vigorous PA (MVPA), and adiposity have noted a very limited evidence base.[11]

The wide variety of accelerometer data reduction methods in the literature also means that it is difficult to determine a dose–response association between accelerometer measured MVPA and adiposity. Walking behavior, as measured by pedometers, is a much simpler concept than MVPA, leading to simpler measurement and lending itself to simpler translation to public health messages. Therefore, because of the growing number of studies using pedometers, and the public health value of walking as a concept, and the practical utility of pedometers in population-based approaches to obesity prevention, an updated revision regarding the association of PA determined by pedometers and adiposity would be of interest. In the present review,

Submitted for publication September 30, 2016; accepted November 25, 2016.

*From the *GENUD (Growth, Exercise, Nutrition and Development) Research Group, University of Zaragoza, Zaragoza, Spain; †Instituto Agroalimentario de Aragón (IA2); ‡Division of Developmental Medicine, Yorkhill Hospitals, University of Glasgow Medical Faculty, Glasgow, Scotland; §Faculty of Health Science, University of Zaragoza, Zaragoza, Spain; ¶Centro de Investigación Biomédica en Red de Fisiopatología de la Obesidad y Nutrición (CIBERObn); and ‖GALENO Research Group, Department of Physical Education, University of Cádiz, Puerto Real (Cádiz) Spain.*

The authors report no conflicts of interest.

Corresponding Author: María L. Miguel-Berges, MSc, BsC, Pedro Cerbuna, 12, 50009 Zaragoza, Spain (mlmiguel@unizar.es).

http://dx.doi.org/10.1097/JSM.0000000000000419

the main objective was to systematically review the original studies investigating the relationship between walking and adiposity of children and adolescents.

METHODS

The protocol used for the systematic review is Preferred Reporting Items for Systematic reviews and Meta Analyses (PRISMA).[12] For the assessment of the quality of the included studies where it are shown in the Table 3, was used The Evidence Analysis Manual was created by the Academy of Nutrition and Dietetics.[13]

Search Strategy

The search was conducted in the following databases—Cochrane Library (CENTRAL), the OVID (MEDLINE, Embase, and PsycINFO), EBSCOhost (Sportdiscus), and PEDro—from the beginning to July 2015. PubMed database was also used for double checking. The search period was chosen as pedometer usage is recent, and we wanted to include all the literature available. In addition, manual searching of reference lists were carried out and results combined in EndNote. Keywords used were "pedometer" and "pedometer and physical activity."

The searches by these terms resulted in 304 potentially eligible articles, from which duplicates, checking titles, and

TABLE 1. Recent Longitudinal/Intervention Studies of Associations Between Walking Behavior by Pedometers and Adiposity in Youth

Study	Exposure Variable	Outcome Variable	Location/Participants	Conclusions	Overall Result
14	Number of daily steps 7 days, waking hours (pedometer Digiwalker SW-200)	Continuous variable	N = 589 children (310 intervention, 287 boys) aged 7-11 years at baseline 10 months intervention, Northeast of England	Both control and intervention participants had increased their physical activity at follow-up. There was no clear effect of increased PA on body composition.	(NA)
		BMI			
		WC			
		SC and TC skinfolds			
		% body fat			
16	Number of daily steps 4 consecutive weekdays (Yamax pedometers Digiwalker SW-200, Tokyo, Japan)	Continuous variable	N = 93 children aged 7-14 years at baseline 3-year follow-up, Sweden	Year 3: an SIG increase in BMI in boys and girls, while an SIG decrease in daily steps in. boys were found.	—
		BMI			
17	Number of daily steps 7 consecutive days (5 times) (Yamax Digiwalker SW-200)	Categorical variable	N=177 children (89 intervention, 45 boys) aged 6-9 years at baseline 2-year intervention, The Czech Republic	Year 1: PA increase and the odds of being overweight or obese in the intervention children were almost 3 times lower than that of control children. Year 2: these odds steadily decreased with the duration of the intervention.	—
		Obesity			
		Overweight			
		Normal weight			
19	Number of daily steps 8 consecutive days (Yamax pedometer, Tokyo, Japan, MLS-2000)	Continuous variable	N = 606 (315 girls) aged 9.8 years at baseline 12-week intervention, Arizona, United States	Results indicated the treatment was effective at increased PA level of children, especially girls. NSIG differences between were found for BMI.	(NA)
		BMI			
20	Number of daily steps 4 days (including weekend day) (Yamax Digiwalker SW700, Tokyo, Japan)	Categorical variable	N = 85 girls, aged 16 year, 12-week intervention, Australia	PA increases do not provide postintervention changes in any group for BMI.	(NA)
		Obesity			
		Normal weight			
		Underweight			
18	Number of daily steps 7 days (pedometer Omron HJ-720ITC; Omron Healthcare, Lake Forest, Illinois)	Continuous variable	N = 285 children (147 intervention and 138 control) aged 6-12 years at baseline 9-month intervention, Singapore	PA increases do not provide changes in BMI	(NA)
		BMI			

BMI, body mass index; PA, physical activity; NSIG, no significant; SIG, significant; SC, Subscapular, TC, triceps; WC, waist circumference.

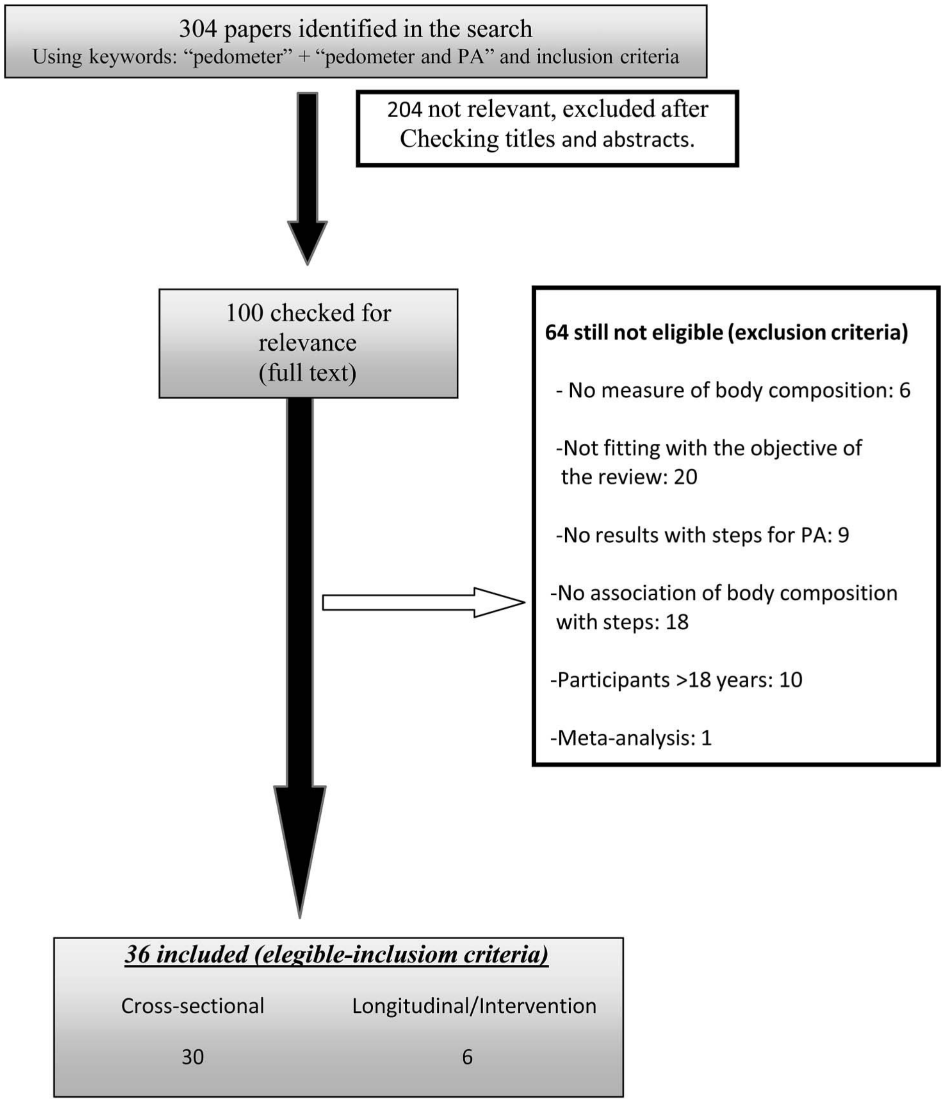

Figure 1.
Flow diagram of the literature search and article selection.

abstracts were eliminated by applying the inclusion and exclusion criteria derived in the final eligible articles (Figure 1).

Eligibility Criteria

Eligible studies were longitudinal and cross-sectional observational studies of healthy children and adolescents (0-18 years) that tested for the existence of associations between walking using pedometers and adiposity. Studies were only included when they attempted to measure typical or "habitual" freeliving PA; studies that measured PA in confined conditions (eg, within whole-body calorimeters) were excluded. Community-based (nonclinical) studies with a measure of walking (pedometer-determined) as the exposure variable and with at least one weight-based outcome indicative of adiposity were included. Studies that used, exclusively, other objective methods for PA such as accelerometry or heart rate monitor were excluded. Studies in clinical populations, not in the English/Spanish languages, or proxy measures of habitual PA (eg, physical education time) were also excluded. In addition, duplicate publications were excluded, and in all cases of duplicates, the first publication was selected for inclusion. Doubts over eligibility of individual articles/studies were resolved by discussion and consensus between the authors. Reasons for excluding articles were noted and are available from the corresponding author on request.

Data Management and Extraction

Characteristics of each study were extracted and summarized: the exposure variable (s) used; methodology for measurement of the exposure variable; the outcome variable (s) used; methodology for measurement of the outcome variable (s) (adiposity measure, proxy, or index); sample size, location, and characteristics; and results and main conclusions relevant to the present review.

Sensitivity Analyses

Age of Study Participants

Studies were stratified by age range of study participants into preschool children (up to 5.5 years), children (5.5-10.5

TABLE 2. Cross-Sectional Studies of Associations Between Walking Behavior by Pedometers and Adiposity in Youth

Study	Exposure Variable	Outcome Variable	Location/Participants	Conclusions	Overall Result
43	Number of daily steps, 4 consecutive weekdays (Yamax, SW-200, Digiwalker, Tokyo, Japan)	Categorical variable	N = 871 children, aged 7-9 years, Sweden.	Analysis of step counts and BMIs for boys and girls revealed NSIG correlations in any age group.	(NA)
		Overweight/obesity			
		Normal weight			
45	Number of daily steps, 7 days (Digiwalker 200SW)	Continuous variable	N = 120 children, aged 9-11 years, United States.	Overweight children were more sedentary at baseline than underweight and normal weight children (cross-sectional data)	—
		BMI (kg/m^2)			
30	Number of daily steps, 7 days (at least 4 days; 3 weekdays and 1 weekend) (Yamax Digiwalker SW-200)	Continuous variable	N = 301 (153 boys) aged 6-9 years, Dublin.	Significant differences were found in normal and overweight, and normal and obese children's step counts	—
		BMI (kg/m^2)			
33	Number of daily steps, 3 weekdays and 2 weekend days (pedometers Model NL-2000, New Lifestyles)	Categorical variable	N = 1115 children (536 boys) aged 5-12 (8.5) years, New Zealand.	Categorical variable	—
		Normal weight		SIG difference in weekend PA among the weight status categories	
		Overweight			
		Obesity			
		Continuous variables		Continuous variables	
		BMI (kg/m^2)		SIG negative associations between PA and %BF, BMI, and WC. Stronger association with %BF categories	
		WC			
		% BF (by BIA)			
35	Step count quartiles– I: <10 000; II: 10 000-12 000; III: 12 000-14 000; and IV: >14 000, 7 days (at least 4 days; 3 weekdays and 1 weekend). (Digiwalker 200SW)	Categorical variables	N = 608 children, aged 9.6 years, United States.	Categorical variables	—
		Overweight		SIG increase in odds of overweight and obesity and high WC with lower count quartiles	
		Obese			
		Continuous variables		Continuous variables	
		BMI (kg/m^2)		SIG negative associations between step count, BMI, and WC	
		WC			
36	Number of daily steps, 3 days (pedometer Yamax Digiwalker SW-200)	Categorical variables	N = 315 children (162 boys), aged 9-13 years, London.	Categorical variables	—
		Underweight		Male and female obese individuals had the lowest total step counts per day	
		Normal weight			
		Overweight			
		Obese			
		Continuous variables		Continuous variables	
		BMI Z-score		There was a SIG negative correlation between BMI z-scores and number of steps per day in girls	
39	Number of daily steps, 7 days (at least 4 days; 3 weekdays	Categorical variables	N = 709 children, aged 7-12 years, United States.	Categorical variables	—

TABLE 2. Cross-Sectional Studies of Associations Between Walking Behavior by Pedometers and Adiposity in Youth *(Continued)*

Study	Exposure Variable	Outcome Variable	Location/Participants	Conclusions	Overall Result
	and 1 weekend) (pedometer Digiwalker SW-200)				
		Underweight		Boys and girls accumulating fewer than 13 000 and 11 000 steps per day, respectively, were 2.74 and 2.37 times more likely to be overweight than those that met the recommendations	
		Normal weight			
		Overweight			
		Obese			
		Continuous variables		Continuous variables	
		BMI		There was a SIG negative correlation between BMI and number of steps per day in boys and girls	
32	Number of daily steps, 3 weekdays (pedometer Yamax SW-200 Digiwalker, Yamasa Corp., Tokyo, Japan)	Continuous variables	N = 178 children, aged 9-12 years, Canada.	BMI z-score and WC were negatively correlated with pedometer step counts	—
		BMI z-score			
		WC z-score			
34	Number of daily steps, 4 consecutive days (2 weekdays, 2 weekend days) (pedometer New Lifestyles, NL-2000, Montana, USA)	Categorical variables	N = 496 children (224 boys) aged 8-14 years, England.	Categorical variables	—
		Normal weight		PA in the weekdays SIG decreases across weight status categories in children	
		Overweight			
		Obese			
		Continuous variables		Continuous variables	
		BMI		Mean steps taken during weekend days are SIG associated with reduced BMI and LBMI in children	
		LBMI			
28	Number of daily steps, 3 consecutive weekdays (pedometer Digiwalker)	Categorical variables	N = 224 (109 boys) aged 3, 4-6, and 4 years, Arabia Saudi.	Categorical variables	(NA)
		Nonobese		Nonobese children had higher steps count per day than obese peers (7064.5 versus 5374.6), but the difference was NSIG.	
		Obese			
		Continuous variables		Continuous variables	
		Sum of 2 SC and TC		No differences were found between active (≥10 000) and inactive children for any of the adiposity indexes calculated	
		FMI			
		%FM			
		FM			
		FFM			
		FFMI			
38	Number of daily steps, 8 days (at least 4 days) (pedometer Yamax Digiwalker SW-700)	Categorical variables	N = 1539 adolescents (787 boys) aged 9-16 years, Australia.	Categorical variables	—

TABLE 2. Cross-Sectional Studies of Associations Between Walking Behavior by Pedometers and Adiposity in Youth *(Continued)*

Study	Exposure Variable	Outcome Variable	Location/Participants	Conclusions	Overall Result
		Normal vs high trunk fat (WC)		There were a trend to higher levels of PA in normal weight group compared with the ow/ob group, but only SIG in the age groups 9-10 and 9-11 years in boys and girls, respectively. Similarly, those with normal trunk fat had higher PA levels compared with those with high trunk fat in age groups 15-16 and 7-12 years in boys and girls, respectively	
		obese versus normal weight			
		Continuous variables		Continuous variables	M (-), F (NA)
		BMI		There was no relationship between BMI and mean daily steps count for either male or females and only a small but significant relationship between WC and PA for males	
		WC			
27	Number of daily steps, 3 continuous weekdays (pedometer Yamax Digiwalker SW-701)	Categorical variables	N = 296 children aged 8-12 years, Arabia Saudi.	Categorical variables	—
		Obese versus normal weight		Mean step counts for the obese group were significantly lower than in the normal group	
		Obesity (>25% FM) versus normal weight		Continuous variables	
		Continuous variables			
		TC and SC skinfolds		There were SIG differences between active (>13 000 steps/day) and inactive boys in body weight, BMI, triceps and subscapular skinfolds, % FM, and FMI	
		FM			
		FMI			
29	Number of daily steps, 4 consecutive weekdays (pedometer Walk4Life MLS 2525, Plainfield, IL, and YAMAX SW-200, Tokyo, Japan for the 60% and 40% of the sample, respectively)	Categorical variables	N = 1067 children (434 boys) aged 6-12 years, United States.	Descriptive information shows a tendency to lower levels of PA in those at risk of overview compared with normal weight, but no statistical analyses were performed. Further analyses showed that steps counts were unable to distinguish between youth in a healthy or unhealthy weight.	(NA)
		Normal weight			
		At risk of an overweight			
41	Number of daily steps, 7 days (pedometer Lifecorder EX, Suzuken Co., Nagoya, Japan)	Continuous variables	N = 216 (105 boys) aged 9-10 years, Japan.	The steps counts were negatively correlated with obesity indices in both sexes (stronger in girls)	—
		BMI			
		%BF by BIA			
42	Number of daily steps, 2 weekdays (pedometer Yamax SW-200 Digiwalker, Yamasa Corp., Tokyo, Japan)	Categorical variables	N = 82 adolescents (34 males) aged 9-12 years, E Canada.	The pedometer step counts did not differ among body weight categories	(NA)
		Normal weight			
		Overweight			
		Obese			

TABLE 2. Cross-Sectional Studies of Associations Between Walking Behavior by Pedometers and Adiposity in Youth *(Continued)*

Study	Exposure Variable	Outcome Variable	Location/Participants	Conclusions	Overall Result
40	Number of daily steps, 3 days (electronic pedometer, Yamasa, Japan)	Categorical variables	N = 30 children, aged 12 years, Japan.	Categorical variables	—
		Obese vs nonobese (>30% BF)		There was significant difference in step counts per day between the obese and the nonobese.	
		Continuous variables		Continuous variables	
		% BF (from skinfolds)		There was a correlation between the pedometer step counts and the percentage of body fat	
46	Number of daily steps, 4 consecutive weekdays. Yamax pedometers (namely as My Life Stepper MLS-2000; or New Lifestyles Digiwalker SW-200)	Categorical variables	N = 1954 children aged 6-12 years, United states, Australia, and Sweden	The direction confirms the intuitive expectation that children who are less active tend to have higher values of BMI. Correlation analysis found few SIG negative relationships between step counts and BMI with an age- and country-specific effect	—
		Normal weight			
		Overweight/obese			
		Continuous variables			
		BMI			
31	Average of daily steps, 5-8 days (Yamax Digiwalker SW-701)	Continuous variables BMI	N = 297, aged 13-15-years, Australia	SIG negative association between BMI and PA	—
47	Average of daily steps, 6 days (Yamax SW-200)	Continuous variables	N = 296 (163 girls, 129 boys), aged 11-14 years, United states.	SIG negative association between %BF and PA	—
		% Body fat			
44	Average of daily steps, 4 consecutive days (Yamax SW700 Digiwalker)	Categorical variables	N = 415 girls, aged 16 years, Australia.	The girls who achieved less than 10 000 steps/day were SGI more likely to be overweight or obese	—
		Underweight			
		Normal weight			
		Overweight			
		Obese			
37	Number of daily steps, 4 days (1 weekend) (Yamax Digiwalker SW-200; Tokei Keiki Co. Ltd., Tokyo, Japan)	Continuous variable	N = 1585 adolescents (771 girls, 814 boys), aged 14 years, Australia.	BMI did not significantly correlate with physical activity for the males and females. Multiple regression analyses showed aerobic fitness and body composition were significant predictors of PA only for males	(-, only males)
		BMI			
10	Number of daily steps, 3 weekdays and 2 weekend days. (Model NL-2000, New Lifestyles Inc., Lee's Summit, MO)	Continuous variables	N = 969 children (454 boys, 515 girls), aged 5-12 years, Auckland, New Zealand.	Children classified as overweight using %BF had significantly lower step counts than their nonoverweight counterparts.	—
		BMI			
		% Body fat			
21	Average of daily steps, 5 consecutive days, (Yamax SW-200)	Continuous variable	N = 829 students (400 boys, 429 girls), aged 9.6 years, University Review Board.	Normal weight children had higher step counts than obese children. Normal weight group had significantly more steps than the overweight group.	—
		BMI			
22	Number of daily steps, 2 weekdays and 2 weekend days (New Lifestyles, NL-2000; New Lifestyles Inc., MT, USA)	Continuous variable	N = 536 (255 boys, 281 girls) aged 9.6 years, Asian children.	BMI was negatively associated with steps/day	—
		BMI			

TABLE 2. Cross-Sectional Studies of Associations Between Walking Behavior by Pedometers and Adiposity in Youth *(Continued)*

Study	Exposure Variable	Outcome Variable	Location/Participants	Conclusions	Overall Result
23	Number of daily steps during 1 week. New Lifestyles SW-200 pedometers.	Continuous variable	N = 114 children, aged 8-12 years, United States.	Children with normal weight took 1858 more steps per day than children with overweight at day	—
		BMI			
24	Average of daily steps, 7 consecutive days (Yamax SW-200)	Continuous variable	N = 491 children (56.4% females) aged 7.9-11.9 years, Ottawa, Canada.	Weight status was not significantly correlated with step counts	(NA)
		BMI			
		Waist circumference			
25	Average of daily steps, 5 consecutive days. Yamax Digiwalker DW-200, Tokyo, Japan)	Continuous variable	N = 104 children (54 boys, 50 girls), aged 7.9-11.9 years, Cypriot.	Children with a BMI value above the 85th percentile scored significantly lower steps/d than children with a BMI value below the 85th percentile	—
		BMI			
26	Average of daily steps, 5 school days. (Yamax Digiwalker SW-200, New Lifestyles, Lee's Summit, Missouri).	Continuous variable	N = 916 (53% male), aged 5-6 years, Bronx, New York.	There were no statistically significant differences found in average number of steps taken per school day among normal weight, overweight, and obese students	(NA)
		BMI			
48	New Lifestyles 1000	Categorical variables	N = 2200 children, aged 9-16 years, Australia.	Thin adolescents walked significantly further than obese adolescents with the mean values of 10 916 steps/day and 9552 steps/day, respectively	—
		Underweight			
		Normal weight			
		Overweight			
		Obese			
49	Average of daily steps, 7 school days. The Yamax SW-200 (Yamax Corp., Tokyo, Japan)	Categorical variables	N = 133 children, aged 8-11 years, Midwestern US.	Children's BMI and BMI z-score were negatively correlated with pedometer steps. Overweight and obese children took fewer pedometer steps than normal weight children	—
		Normal weight			
		Overweight			
		Obese			
		Normal weight			

BMI, body mass index; FMI, fat mass index; LBMI, lean body mass index; ob, obesity; ow, overweigth; SC, Subscapular, TC, triceps; WC, waist circumference; PA, physical activity.

years), and adolescents (10.5-18 years) to examine possible age-dependence of relationships between walking and adiposity.[14] The precise age categories chosen made little difference to the conclusions of the present review.

Outcome Measure(s)

A variety of different measures of adiposity or indices of adiposity were used in the studies reviewed, falling into 2 categories: proxies for adiposity [body mass index (BMI) and waist circumference] and more precise measures of adiposity such as skinfolds thickness or bioelectrical impedance analysis (BIA).

Exposure Measure

The method used to measure PA was only pedometry. This has become a popular PA assessment tool,[10] capturing objective PA data,[8] specifically walking behavior.

2.7 Sample Size

The studies reviewed were characterized by a very wide range of sample sizes. Sample size is likely to determine the ability to detect associations between walking behavior and adiposity. Publication bias is also possible, and small studies that find no association between walking and adiposity are less likely to be published than small studies that find significant associations. In an attempt to address the influence of sample size on the confidence in any conclusions reached, studies were categorized by sample size in the present review as "large studies" n > 1000 participants; "medium sized studies," n ≥ 100 to 1000 participants; and "small studies," n < 100 participants.

Consistency of Evidence

The scheme proposed by Sallis et al[15] was used to summarize the consistency of the body of evidence as previously used to infer the degree of confidence in the conclusions. "Strong evidence" of an association exists when 60%-100% of studies find significant associations in the same direction.

RESULTS

Overall Results

Of the 304 potentially eligible articles, 36 were eligible and included and are summarized in the present review (Figure 1 is a flow diagram describing the search and selection process).

Only 17% (6/36) of eligible studies were longitudinal[14,16–20] (Table 1), from which 83% (5/6) were intervention studies. Most studies [83% (30/36)] were cross sectional[10,21–49] (Table 2). Only 6% (2/36) of studies focused on children younger than 5.5 years old. Most studies [80% (29/36)] included children and adolescents aged 5.5 to 10.5 years, whereas 5/36 (14%) studies included adolescents aged >10.5 to 18 years. However, all the studies included BMI as a proxy for adiposity, and 19% of studies (7/36) also measured waist circumference. However, only 25% (9/36) of studies used more precise measures of body composition such as skinfolds and/or BIA. The studies reviewed here consistently reported significant and negative associations between walking and adiposity (25/35; 71%), indicating "strong evidence" that such an association exists with higher levels of walking being associated with lower measures or indices of adiposity. In the cross-sectional studies, 24/30 (80%) of them found significant negative associations, and in the longitudinal studies, 2/6 (33%) of studies found significant negative associations while the other studies found a nonsignificant trend in the "expected" direction.

Results by Outcome Measure

Significant negative associations between pedometer-determined physical activity and adiposity were found in 16/23 (70%) of studies that used simple proxies for adiposity as the outcome measure and 10/13 (77%) of studies that used more precise body composition variables such as skinfolds and waist circumference as the outcome measure.

Results by Sample Size

7/36 (19%) of studies were "large" (n > 1000 participants), 25/36 (69%) "medium size" (n = 100-1000 participants), and 4/36 (11%) "small size" (n < 100 participants). 86% (6/7) of the large studies found significant negative associations, whereas the corresponding percentage was 72% (18/25) in the medium sized studies and 50% (2/4) in the small studies.

Results by Pedometers Model

Twenty of 36 (56%) of studies used the same pedometer model, the Yamax Digiwalker SW-200 series which has consistently been found among the most accurate of the pedometers. The Yamax SW-200 is recommended as a reliable monitor for use in children[2] and is the most commonly used pedometer to assess PA and walking among children.[49]

Only one meta-analysis was found, and the results support the fact that the use of pedometers has a moderate and positive effect on the increase of PA in intervention studies.

DISCUSSION

The studies summarized in the present review represent a large body of evidence that reported significant and negative associations between pedometer-determined physical activity and adiposity with a high degree of consistency, probably indicating "strong evidence" that such an association exists.[15] The present review therefore supports the view that variation in the level of walking in youth is a contributor to variation in weight status. This study supports the hypothesis that higher levels of walking are protective against increased adiposity in youth and so supports the use of walking as a promotion as a strategy for obesity prevention.

This study found a number of evidence gaps and weaknesses which future research could address. Relatively few studies tested for associations between pedometer-determined physical activity and adiposity in the preschool population, and among the studies on school-age children and adolescents, there were far fewer studies of adolescents than children. Many studies did not consider differences in associations between pedometer-determined physical activity and adiposity between the sexes, but it may be noteworthy that the evidence summarized here contained a suggestion that significant negative associations may be found more commonly among boys than girls and that associations may be stronger in boys than girls. Future research would be required to address the issue of sex differences more conclusively, but boys are usually more physically active than girls, as suggested by many reviews,[1,2,6,8,9,14,29,35,36,41,43] and in a previous systematic review of associations between accelerometer measured physical activity (not specifically walking) and adiposity in youth, there was a suggestion of consistently stronger associations in boys than girls.[1]

Numerous descriptive studies have implemented pedometers to assess weekday walking in children and adolescents, yet comparatively few have obtained separate data representing weekend days. The number of steps taken by children on the weekends is of particular interest, given the current evidence that young people are less active when outside the school environment.[3] The strong associations highlighted in this review provide support to the use of pedometers in studies of the etiology of obesity in youth, although the limitations of measuring only the numbers of steps should always be considered, and where resources permit alternative methods of measuring physical activity (eg accelerometry) should also be considered. Only one meta-analysis was found, and the results support the fact that the use of pedometers has a moderate and positive effect on the increase of PA in intervention studies.[50]

Publication bias may well have influenced the literature on associations between pedometer-determined physical activity and adiposity in youth. No formal test for publication bias was performed in this study, but the conclusions of larger studies (n > 1000) reviewed were actually more supportive (86% of studies found significant negative associations) of the hypothesis that higher levels of walking protects against high adiposity than the conclusions of smaller studies (n < 100; 50% of studies found significant negative associations), and this conclusion was independent of the method used to

TABLE 3. Quality Assessment of the Included Studies by the Evidence Analysis Manual

Author	Overall	Was the Research Question Clearly Stated?	Was the Selection of Study Subjects/ Patients Free From Bias?	Were Study Groups Comparable?	Was the Method of Handling Withdrawals Described?	Was Blinding Used to Prevent Introduction of Bias?	Were Intervention/ Therapeutic Regimens/ Exposure Factor or Procedure and Any Comparison Described in Detail? Were Intervening Factors Described?	Were Outcomes Clearly Defined and the Measurements Valid and Reliable?	Was the Statistical Analysis Appropriate for the Study Design and Type of Outcome Indicators?	Are Conclusions Supported by Results With Biases and Limitations Taken Into Consideration?	Is a Bias Due to Study's Funding or Sponsorship Unlikely?
14	+	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No
16	+	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
17	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
19	−	Yes	No	No	No	No	Yes	No	No	Yes	No
20	+	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
18	Ø	Yes	Yes	N/A	No	No	N/A	No	N/A	Yes	No
43	Ø	Yes	Yes	N/A	Yes	No	Yes	Yes	Yes	Yes	Yes
45	+	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
30	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
33	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	N/A
35	−	Yes	Yes	No	No	No	No	N/A	Yes	Yes	Yes
36	Ø	Yes	Yes	N/A	Yes	No	Yes	Yes	Yes	Yes	N/A
39	Ø	Yes	Yes	N/A	No	No	Yes	Yes	Yes	Yes	Yes
32	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
34	+	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
28	Ø	Yes	Yes	N/A	No	No	Yes	Yes	Yes	Yes	Yes
38	Ø	Yes	Yes	N/A	No	No	Yes	Yes	Yes	Yes	N/A
27	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
29	Ø	Yes	Yes	N/A	No	No	Yes	Yes	Yes	Yes	N/A
41	−	N/A	Yes	No	No	No	No	N/A	Yes	Yes	N/A
42	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	N/A
40	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	N/A
46	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes
31	Ø	Yes	Yes	No	No	No	N/A	Yes	Yes	Yes	Yes
47	−	Yes	Yes	No	No	No	Yes	No	No	No	Yes
44	Ø	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No
37	−	Yes	No	No	No	No	Yes	N/A	Yes	Yes	No
10	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	N/A
21	−	Yes	No	No	No	No	Yes	N/A	Yes	Yes	No
22	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	N/A
23	−	Yes	No	No	No	No	Yes	N/A	Yes	Yes	No
24	Ø	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No
25	Ø	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No
26	Ø	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No
48	+	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	N/A
49	−	Yes	No	No	No	No	Yes	N/A	Yes	Yes	No

categorize sample size. An additional limitation of the literature was that because of the predominance of cross-sectional studies, it is difficult to rule out bidirectionality–the possibility that higher adiposity might reduce walking. Greater confidence about causal relationships between pedometer-determined physical activity and adiposity would also require a greater body of evidence from longitudinal and intervention studies–the present review suggests that there is a distinct lack of evidence from these study designs. Finally, the body of evidence identified from this study was too limited and too heterogeneous to attempt to assess "dose-response" relationships between physical activity and adiposity–future research should attempt to identify the "dose-response."

CONCLUSION

The present review supports the hypothesis that higher levels of walking behavior are against higher levels of child and adolescent adiposity. However, prospective longitudinal studies using more precise methods of body composition are warranted; there is a need for more research on younger children, in a wider variety of settings and populations, and for more "dose-response" evidence.

Detecting strong evidence of this association using pedometers not only implies its utility in monitoring walking levels but also could help us as a tool in promoting physical activity patterns by means of motivational aspects.

ACKNOWLEDGMENTS

The authors thank the researchers for contributing to research and the coauthors for their help in the search, drafting, and review the article.

References

1. Jimenez-Pavon D, Kelly J, Reilly JJ. Associations between objectively measured habitual physical activity and adiposity in children and adolescents: systematic review. *Int J Pediatr Obes.* 2010;5:3–18.
2. Rowlands AV, Eston RG, Ingledew DK. Measurement of physical activity in children with particular reference to the use of heart rate and pedometry. *Sports Med.* 1997;24:258–272.
3. Clemes SA, Biddle SJ. The use of pedometers for monitoring physical activity in children and adolescents: measurement considerations. *J Phys Act Health.* 2013;10:249–262.
4. McNamara E, Hudson Z, Taylor SJ. Measuring activity levels of young people: the validity of pedometers. *Br Med Bull.* 2010;95:121–137.
5. Tudor-Locke C, McClain JJ, Hart TL, et al. Expected values for pedometer-determined physical activity in youth. *Res Q Exerc Sport.* 2009;80:164–174.
6. Lubans DR, Morgan PJ, Tudor-Locke C. A systematic review of studies using pedometers to promote physical activity among youth. *Prev Med.* 2009;48:307–315.
7. Tudor-Locke C, Williams JE, Reis JP, et al. Utility of pedometers for assessing physical activity: construct validity. *Sports Med.* 2004;34: 281–291.
8. Tudor-Locke C, Williams JE, Reis JP, et al. Utility of pedometers for assessing physical activity: convergent validity. *Sports Med.* 2002;32: 795–808.
9. Oliver M, Schofield GM, Kolt GS. Physical activity in preschoolers: understanding prevalence and measurement issues. *Sports Med.* 2007;37: 1045–1070.
10. Duncan JS, Schofield G, Duncan EK. Step count recommendations for children based on body fat. *Prev Med.* 2007;44:42–44.
11. Ekelund U, Hildebrand M, Collings PJ. Physical activity, sedentary time and adiposity during the first two decades of life. *Proc Nutr Soc.* 2014;73: 319–329.
12. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *J Clin Epidemiol.* 2009;62:e1–e34.
13. *Evidence analysis manual: Steps in the academy evidence analysis process.* American Dietetic Association; 2012.
14. Gorely T, Morris JG, Musson H, et al. Physical activity and body composition outcomes of the GreatFun2Run intervention at 20 month follow-up. *Int J Behav Nutr Phys Act.* 2011;8:74.
15. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc.* 2000;32:963–975.
16. Raustorp A, Mattsson E, Svensson K, et al. Physical activity, body composition and physical self-esteem: a 3-year follow-up study among adolescents in Sweden. *Scand J Med Sci Sports* 2006;16:258–266.
17. Sigmund E, El Ansari W, Sigmundova D. Does school-based physical activity decrease overweight and obesity in children aged 6-9 years? A two-year non-randomized longitudinal intervention study in the Czech Republic. *BMC Public Health.* 2012;12:570.
18. Finkelstein EA, Tan YT, Malhotra R, et al. A cluster randomized controlled trial of an incentive-based outdoor physical activity program. *J Pediatr.* 2013;163:167–172.e1.
19. Pangrazi RP, Beighle A, Vehige T, et al. Impact of promoting lifestyle activity for youth (play) on children's physical activity. *J Sch Health.* 2003; 73:317–321.
20. Schofield L, Mummery WK, Schofield G. Effects of a controlled pedometer-intervention trial for low-active adolescent girls. *Med Sci Sports Exerc.* 2005;37:1414–1420.
21. Brusseau TA, Kulinna PH, Tudor-Locke C, et al. Pedometer-determined segmented physical activity patterns of fourth- and fifth-grade children. *J Phys Act Health.* 2011;8:279–286.
22. Duncan MJ, Birch S, Al-Nakeeb Y, et al. Ambulatory physical activity levels of white and South Asian children in Central England. *Acta Paediatr.* 2012;101:e156–e162.
23. Hickerson BD, Henderson KA. Opportunities for promoting youth physical activity: an examination of youth summer camps. *J Phys Act Health.* 2014;11:199–205.
24. Larouche R, Boyer C, Tremblay MS, et al. Physical fitness, motor skill, and physical activity relationships in grade 4 to 6 children. *Appl Physiol Nutr Metab.* 2014;39:553–559.
25. Loucaides CA, Jago R. Correlates of pedometer-assessed physical activity in Cypriot elementary school children. *J Phys Act Health.* 2006;3:267.
26. Reznik M, Wylie-Rosett J, Kim M, et al. Physical activity during school in urban minority kindergarten and first-grade students. *Pediatrics.* 2013; 131:e81–e87.
27. Al-Hazzaa HM. Pedometer-determined physical activity among obese and non-obese 8- to 12-year-old Saudi schoolboys. *J Physiol Anthropol.* 2007;26:459–465.
28. Al-Hazzaa HM, Al-Rasheedi AA. Adiposity and physical activity levels among preschool children in Jeddah, Saudi Arabia. *Saudi Med J.* 2007;28: 766–773.
29. Beets MW, Le Masurier GC, Beighle A, et al. Are current body mass index referenced pedometer step-count recommendations applicable to US youth? *J Phys Act Health.* 2008;5:665–674.
30. Belton S, Brady P, Meegan S, et al. Pedometer step count and BMI of Irish primary school children aged 6-9 years. *Prev Med.* 2010;50:189–192.
31. Cuddihy T, Michaud-Tomson L, Jones EK, et al. Exploring the relationship between daily steps, body mass index and physical self-esteem in female Australian adolescents. *J Exerc Sci Fitness.* 2006;4: 25–35.
32. Downs SM, Marshall D, Ng C, et al. Central adiposity and associated lifestyle factors in Cree children. *Appl Physiol Nutr Metab.* 2008;33: 476–482.
33. Duncan JS, Schofield G, Duncan EK. Pedometer-determined physical activity and body composition in New Zealand children. *Med Sci Sports Exerc.* 2006;38:1402–1409.
34. Duncan MJ, Nevill A, Woodfield L, et al. The relationship between pedometer-determined physical activity, body mass index and lean body mass index in children. *Int J Pediatr Obes.* 2010;5:445–450.
35. Eisenmann JC, Laurson KR, Wickel EE, et al. Utility of pedometer step recommendations for predicting overweight in children. *Int J Obes (Lond).* 2007;31:1179–1182.
36. Finnerty T, Reeves S, Dabinett J, et al. Effects of peer influence on dietary intake and physical activity in schoolchildren. *Public Health Nutr.* 2010; 13:376–383.
37. Hands B, Larkin D, Parker H, et al. The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Scand J Med Sci Sports.* 2009;19:655–663.
38. Hands B, Parker H. Pedometer-determined physical activity, BMI, and waist girth in 7- to 16-year-old children and adolescents. *J Phys Act Health.* 2008;5(suppl 1):S153–S165.
39. Laurson KR, Eisenmann JC, Welk GJ, et al. Combined influence of physical activity and screen time recommendations on childhood overweight. *J Pediatr.* 2008;153:209–214.
40. Mikami S, Mimura K, Fujimoto S, et al. Physical activity, energy expenditure and intake in 11 to 12 years old Japanese prepubertal obese boys. *J Physiol Anthropol Appl Hum Sci.* 2003;22:53–60.

41. Munakata H, Sei M, Ewis AA, et al. Prediction of Japanese children at risk for complications of childhood obesity: gender differences for intervention approaches. *J Med Invest*. 2010;57:62–68.
42. Ng C, Marshall D, Willows ND. Obesity, adiposity, physical fitness and activity levels in Cree children. *Int J Circumpolar Health*. 2006;65:322–330.
43. Raustorp A, Pangrazi RP, Stahle A. Physical activity level and body mass index among schoolchildren in south-eastern Sweden. *Acta Paediatr*. 2004;93:400–404.
44. Schofield G, Schofield L, Hinckson EA, et al. Daily step counts and selected coronary heart disease risk factors in adolescent girls. *J Sci Med Sport*. 2009;12:148–155.
45. Southard DR, Southard BH. Promoting physical activity in children with MetaKenkoh. *Clin Invest Med*. 2006;29:293–297.
46. Vincent SD, Pangrazi RP, Raustorp A, et al. Activity levels and body mass index of children in the United States, Sweden, and Australia. *Med Sci Sports Exerc*. 2003;35:1367–1373.
47. Rowe DA, Raedeke TD, Wiersma LD, et al. Investigating the youth physical activity promotion model: internal structure and external validity evidence for a potential measurement model. *Pediatr Exerc Sci*. 2007;19:420–435.
48. Ferrar K, Olds T. Thin adolescents: who are they? What do they do? Socio-demographic and use-of-time characteristics. *Prev Med*. 2010;51:253–258.
49. Ling J, Robbins LB, McCarthy VL, et al. Psychosocial determinants of physical activity in children attending afterschool programs: a path analysis. *Nurs Res*. 2015;64:190–199.
50. Kang M, Marshall SJ, Barreira TV, et al. Effect of pedometer-based physical activity interventions: a meta-analysis. *Res Q Exerc Sport*. 2009;80:648–655.