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Effect of Pedometer-Based Physical Activity Interventions: A Meta-Analysis

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Regular physical activity (PA) improves mental health and reduces the risk of a number of adverse health outcomes, including cardiovascular disease mortality, hypertension, colon cancer, and diabetes mellitus (U.S. Department of Health and Human Services, 1996). Recent PA recommendations state that, in addition to strength and flexibility exercises, adults and older adults should participate in moderate PA for a minimum of 30 min, 5 days each week or vigorous-intensity aerobic PA for a minimum of 20 min, 3 days each week to achieve health benefits (Haskell et al., 2007; Nelson et al., 2007). The PA requirement can also be met through a combination of moderate- and vigorous-intensity activity.

Many studies with different strategies have been conducted to increase the level of PA for people of all ages. One of many strategies applied in intervention studies is the use of pedometers as a motivational tool. Pedometers are simple and inexpensive body-worn motion sensors that researchers and practitioners use to assess and motivate PA behaviors (Tudor-Locke & Bassett, 2004).

The Japanese developed the first electronic pedometer, called a "manpo-kei," meaning "10,000 steps meter" (Hatano, 1993). The goal of 10,000 steps/day gained popularity with the media and in practice and can be traced to Japanese walking clubs and a business slogan that was used more than 30 years ago. Taking 10,000 steps/day appears to be a reasonable goal of daily activity for healthy adults, and studies have documented the health benefits of attaining similar levels (Tudor-Locke & Bassett, 2004; Tudor-Locke, Hatano, Pangrazi, & Kang, 2008). In addition, Le Masurier, Sidman, and Corbin (2003) found that individuals who accumulate 10,000 steps/day are more likely to meet the PA guidelines by engaging in the amount of activity promoted by the Centers for Disease Control and Prevention, and the American College of Sports Medicine (Pate et al., 1995), and the U.S. Surgeon General (U.S. Department of Health and Human Services, 1996).

Pedometers have been recommended for use in PA interventions to motivate individuals to increase their ambulatory PA (DuVall et al., 2004; Tudor-Locke, 2001). Pedometers provide instant feedback to individuals using goal-setting principles (e.g., 10,000 steps/day goal). Most of the pedometer-based intervention studies report an increase in PA by the intervention group, but the magnitude of this increase and the effect of other variables (e.g., age and sex of participants, intervention length) are not known. A meta-analysis of those intervention studies can provide more information about the magnitude of change and the effect of those variables. Thus, the purpose of our study was twofold. The first goal was to use meta-analysis to determine the effectiveness of interventions using pedometer as a motivational tool. The second goal was to determine whether age (i.e., children, adults, older adults, and a combination of age groups) and sex of participants (i.e., male, female, or both), intervention length (i.e., number of intervention weeks), and intervention strategy (i.e., 10,000 steps/day goal, log, individual goal, and others) influence the effect of interventions.

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Method

Data Sources

We identified studies by searching online databases—Medline, Pubmed, Sportdiscus, Google Scholar, AAHPERD National Convention and Exposition database, and Proquest—using the key words "pedometer" and "intervention." We used the reference lists of the studies to crosscheck and extend our search, which covered theses, dissertations, and published articles between January 2000 and August 2007.

Study Selection

The studies we selected met the following criteria: (a) at least one participant group used pedometers daily; (b) pedometers were used as a motivational tool during the intervention; (c) step counts were assessed pre- and postintervention; and (d) the intervention period lasted at least 4 weeks.

Because pedometers are measurement devices and motivational tools, it is difficult to untangle the psychological mechanisms of behavioral reactivity, self-monitoring, and feedback (from steps or that augmented by researchers), as well as the influences of different step goals on behavior. To isolate the effects of behavioral reactivity, some researchers have sealed the pedometers to restrict self-monitoring. However, these studies are not typically identified as intervention designs and were, therefore, not included in our analysis. Regardless, behavioral reactivity to pedometer self-monitoring is usually negligible (Behrens & Dinger, 2007), and is likely to affect the intervention and control groups to a similar degree.

Data Extraction

After studies were identified, we independently coded the studies, and disagreements were resolved by consensus. The following variables were extracted: (a) age and sex of participants, intervention length; (b) intervention strategy; (c) pre- and postintervention step counts; and (d) statistical data. When there was insufficient information to compute an effect size (ES), we contacted a corresponding author from each study to obtain means and/or standard deviations to enable computation of an ES. At least one ES was calculated; additional ESs were calculated based on the moderating variables (i.e., sex, intervention length), if available.

We computed ESs using: (a) mean differences from pre- and postintervention divided by pooled standard deviations; and (b) mean differences between intervention and control groups divided by pooled standard deviations. We entered ESs in the Comprehensive Meta Analysis software (Borenstein, Hedges, Higgins, & Rothstein, 2005), along with confidence intervals (CIs) and number of participants for the computation of the mean ES. We adjusted the mean ESs for sample size.

Data Analysis

We calculated the mean ES and 95% CI using a random effects model. ESs were classified as small = 0.2, medium = 0.5, and large = 0.8, based on Cohen's definition (1988). Heterogeneity of the mean ES was examined using Cochran's Q statistic (Hedges & Olkin, 1985). In addition, we used the I^2 statistic to determine the percentage of total variation across the studies due to heterogeneity (Higgins, Thompson, Deeks, & Altman, 2003). If the Q statistic was significant ($p < .05$), which indicates heterogeneity of effects, we performed the moderator analyses. Using the methods described by Lipsey and Wilson (2001), we examined the effect of each moderator variable using SPSS software version 15.

Results

Search Results

We found 103 articles, including 65 publications, 12 presentations, and 26 theses or dissertations. After a preliminary review, we eliminated 53 studies that were duplicated or did not meet the inclusion criteria. We attempted to retrieve information from the remaining 50 studies; 18 studies did not provide sufficient information for the calculation of the ES. A total of 32 studies provided sufficient data on step counts to compute an ES, expressed as Hedges adjusted *g*, and were included in this analysis.

Overall Effect Size

The ESs are provided in Table 1, and Forest plots are shown in Figure 1. Overall, 50 ESs were calculated from the 32 studies. The quantitative synthesis of the effects yielded a moderate and positive mean ES of 0.68 (95% CI = 0.55, 0.81), using a random effects model. This indicated that pedometers are a useful motivational tool to increase PA participation.

Moderator Analysis

The mean ES was heterogeneous, Q = 215.78, $df = 49$, $p < .001$, $I^2 = 77.31$, which supported an examination of moderator variables. The mean ES was influenced by each of the four moderator variables: age (four groups: children 7–17 years old; adults 18–60 years old; older adults *M*age > 60 years old; and a combination of more than one age group), Qbetween (Qb) = 30.00, $df = 3$, $p < .001$; sex (three groups: men, women, and both), Qb = 41.10, $df =$

2, $p < .001$; intervention length (three groups: less than 8 weeks, between 8 and 15 weeks, and more than 15 weeks), $Qb = 11.63$, $df = 2$, $p = .003$; and intervention strategy (four groups: 10K steps goal [i.e., participants were instructed

Table 1. Characteristics of the studies used in the meta-analysis of pedometer-based interventions

Study	*N*p	Age	Gender	Strategy	Length	Published	ES (g)
Araiza et al. (2006)	15	Adults	Both	10K	< 8 weeks	Yes	0.84
Berry et al. (2007)	40	Children	Both	Other	8–15 weeks	Yes	1.83
Berry et al. (2007)	40	Adults	Both	Other	8–15 weeks	Yes	1.92
Chan et al. (2004)	106	Adults	Both	Other	8–15 weeks	Yes	1.09
Clarke et al. (2007)	93	Adults	Women	Log	8–15 weeks	Yes	1.08
Croteau (2004)	37	Adults	Both	Individual goal	8–15 weeks	Yes	0.57
Croteau et al. (2005)	83	Combo	Both	Individual goal	8–15 weeks	Abstract	0.26
de Block et al. (2006)	8	Older adults	Both	Log	8–15 weeks	Yes	0.91
Decker (2007)	18	Adults	Women	Other	8–15 weeks	No	0.50
Decker (2007)	18	Adults	Women	Other	> 15 weeks	No	0.95
Garner (2002)	10	Adults	Women	Other	< 8 weeks	No	0.28
Glazener et al. (2003)	7	Adults	Women	Individual goal	< 8 weeks	Abstract	0.16
Glazener et al. (2003)	7	Adults	Women	Individual goal	< 8 weeks	Abstract	0.94
Haines et al. (2007)	60	Adults	Both	Individual goal	8–15 weeks	Yes	0.62
Hallmark et al. (2005)	12	Adults	Women	Individual goal	< 8 weeks	Abstract	0.56
Hallmark et al. (2005)	13	Adults	Women	Log	< 8 weeks	Abstract	0.32
Hallmark et al. (2005)	13	Adults	Women	Individual goal	< 8 weeks	Abstract	1.19
Jackson et al. (2006)	286	Adults	Both	Log	8–15 weeks	Abstract	0.35
Jansen (2002)	27	Adults	Men	Other	8–15 weeks	No	0.31
Jensen et al. (2004)	18	Older adults	Women	Other	8–15 weeks	Yes	0.53
Merom et al. (2007)	40	Adults	Both	10K	8–15 weeks	Yes	0.74
Oliver et al. (2006)	61	Children	Both	Other	< 8 weeks	Yes	0.09
Oliver et al. (2006)	29	Children	Boys	Other	< 8 weeks	Yes	-0.04
Oliver et al. (2006)	32	Children	Girls	Other	< 8 weeks	Yes	0.22
Ornes (2006)	53	Adults	Women	Individual goal	< 8 weeks	No	1.28
Ransdell et al. (2004)	27	Combo	Women	Other	> 15 weeks	Yes	0.77
Rogers et al. (2005)	10	Combo	Both	Individual goal	> 15 weeks	Abstract	0.90
Schofield et al. (2005)	23	Children	Girls	Other	8–15 weeks	Yes	1.43
Schofield et al. (2005)	21	Children	Girls	Other	< 8 weeks	Yes	0.72
Schofield et al. (2005)	21	Children	Girls	Other	8–15 weeks	Yes	1.26
Schofield et al. (2005)	23	Children	Girls	Other	< 8 weeks	Yes	1.23
Sherman et al. (2007)	60	Adults	Women	Log	> 15 weeks	Yes	0.89
Shipp (2006)	37	Adults	Men	10K	8–15 weeks	No	0.62
Sidman et al. (2004)	45	Adults	Women	10K	< 8 weeks	Yes	1.17
Sidman et al. (2004)	47	Adults	Women	Individual goal	< 8 weeks	Yes	1.04
Speck & Looney (2001)	24	Adults	Women	Log	8–15 weeks	Yes	0.95
Stovitz et al. (2005)	50	Adults	Both	Other	8–15 weeks	Yes	0.37
Swartz et al. (2003)	18	Adults	Women	10K	8–15 weeks	Yes	0.82
Talbot et al. (2003)	17	Older adults	Both	Log	8–15 weeks	Yes	0.29
Toole et al. (2007)	28	Adults	Women	Individual goal	8–15 weeks	Yes	0.46
Toole et al. (2007)	28	Adults	Women	Individual goal	> 15 weeks	Yes	0.59
Toole et al. (2007)	28	Adults	Women	Individual goal	> 15 weeks	Yes	0.57
Toole et al. (2007)	28	Adults	Women	Individual goal	> 15 weeks	Yes	0.58
Tudor-Locke et al. (2004)	24	Adults	Both	Other	> 15 weeks	Yes	0.93
Vallance et al. (2007)	94	Combo	Both	Log	8–15 weeks	Yes	-0.06
Vallance et al. (2007)	93	Combo	Both	Log	8–15 weeks	Yes	-0.01
Wang (2004)	24	Children	Girls	Other	< 8 weeks	No	0.29
Wang (2004)	22	Children	Girls	Individual goal	< 8 weeks	No	1.21
Winett et al. (2007)	322	Adults	Both	Other	8–15 weeks	Yes	0.21
Winett et al. (2007)	330	Adults	Both	Other	8–15 weeks	Yes	0.23
Overall							**0.68**

Note. Np = number of participants; ES = effect size; Combo = studies that reported results on more than one age group combined; 10K = participants were instructed to take 10,000 steps/day; Log = participants were told to write down their daily steps; Individual goal = participants were given individualized step goals; Other = any other strategy or a combination of strategies.

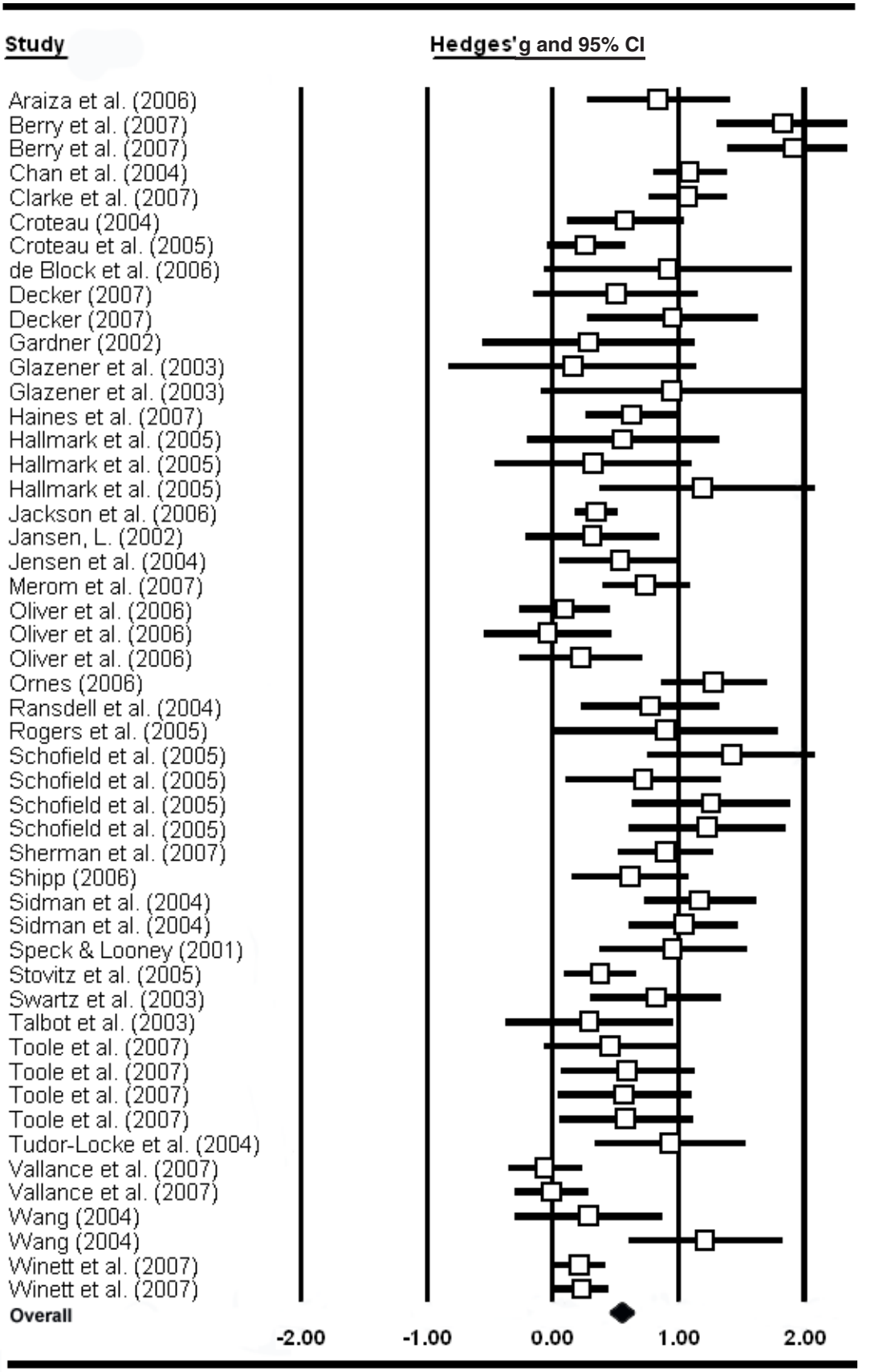

Figure 1. Forest plot: standardized mean difference and 95% confidence interval.

to take 10,000 steps/day]; log [i.e., participants were only told to write down the daily number of steps]; individual goal [i.e., participants were given individualized step goals]; and others [i.e., any other strategy or a combination of strategies]), Qb = 18.96, $df = 3$, $p < .001$. Random model ESs and CI intervals for each moderator variable and publication status are shown in Table 2.

Discussion

The first goal of this study was to use meta-analysis to determine the magnitude and direction of effects in pedometer-based interventions. The results showed that the use of pedometers has a moderate and positive effect on the increase of PA in intervention studies. The second goal was to determine if age and sex of participants, intervention length, and intervention strategy influence the effectiveness of the intervention. The cumulative evidence suggested that all the moderators influence the effect of pedometer-based PA interventions.

The ESs calculated for the different age groups demonstrated that the effects of pedometer use are moderate to high for older adults, adults, and children (ESs = 0.53, 0.72, and 0.78, respectively), but when studies involve a combination of age groups like children and adults, the effect is low (ES = 0.28, 95% CI = -0.10, 0.66). CI included zero due to the small sample size and the conservative approach adopted when random effects calculations are used for ES calculations. This suggests that focusing on one age group can be more effective than when combinations of age groups are studied. This might be due to the varying patterns of PA and effectiveness of instruction in each age group. An intervention strategy that is appropriate for children may not be appropriate for older adults and vice versa.

The ESs calculated for both sexes showed that intervention studies involving only female participants have a greater effect (ES = 0.80, 95% CI = 0.64, 0.97) than when studies involve only male participants or a combination of both. However, the results should be interpreted with caution because only a limited number of studies reported results for men only ($n = 3$; Jansen, 2002; Oliver, Schofield, & McEvoy, 2006; Shipp, 2006), and in the studies that included men and women, most of the participants were female. The results from ES calculations for the intervention length showed that the effects are moderate to high for studies that lasted shorter than 8 weeks, between 8 and 15 weeks, and longer than 15 weeks (ESs = 0.68, 0.65, and 0.76, respectively). Studies lasting longer than 15 weeks in length had a slightly higher ES. However, given the difficulties in having an intervention length of longer than 15 weeks, an intervention length of less than or equal to 15 weeks may be feasible, effective, and inexpensive alternative to longer interventions.

Studies with an intervention strategy of 10,000 steps/day as a goal had the highest ES (ES = 0.84, 95% CI = 0.43, 1.24). Studies that had individualized goals based on the baseline measures, individualized goals with the addition of contact by researchers or practitioners, and other types of intervention methods had similar ESs. The intervention method with the lowest ES simply required participants to fill out a log with the step counts data, which had a moder-

Table 2. Effect sizes by moderators in the meta-analysis of pedometer-based intervention

Moderator variables	*N*	Moderator groups	Mean ES	95% CI	
				From	To
Age (years)	10	Children	0.78	0.49	1.07
	32	Adults	0.72	0.56	0.88
	3	Older adults	0.53	-0.04	1.11
	5	Combination	0.28	-0.10	0.66
Sex	28	Women	0.80	0.64	0.97
	3	Men	0.30	-0.18	0.79
	19	Both	0.57	0.39	0.75
Length	17	< 8 Weeks	0.68	0.45	0.92
	25	8–15 Weeks	0.65	0.47	0.83
	8	> 15 Weeks	0.76	0.42	1.10
Strategy	5	10K goal	0.84	0.43	1.24
	9	Log	0.49	0.19	0.80
	15	Individual goal	0.72	0.47	0.97
	21	Other	0.69	0.49	0.89

Note. *N* = number of effect sizes; ES = effect size; CI = confidence interval; Combination = studies that reported results on more than one age group combined; 10k goal = participants were instructed to take 10,000 steps/day; Log = participants were told to write down their daily steps; Individual goal = participants were given individualized step goals; Other = any other strategy or a combination of strategies.

ate ES of 0.49 (95% CI = 0.19, 0.80). The 10,000 steps/day goal, however, was only used with adults and might not be effective intervention strategy for children and older adults. An additional analysis of adults-only studies was necessary to determine whether the 10,000 steps/day goal was still the most effective strategy for adults. The results confirmed our initial findings of the highest ES from the 10,000 steps/day goal, but there was a noticeable change in the ES of log strategy to 0.73 (95% CI = 0.37, 1.09). As purported by Heesch, Dinger, McClary, and Rice (2005) in their qualitative study, pedometers seem to assist in goal setting (e.g., the 10,000 step/day goal) and increase motivation in physical activity interventions.

To determine if there was any publication bias, we examined the ESs by publication status of the studies. The ES was influenced by the publication status (three groups: published [i.e., full study published]; abstract [i.e., only abstract was published]; and not published), $Qb = 10.23$, $df = 2$, $p = .005$. The ESs between the published and unpublished studies were comparable to the overall mean ES calculated from the meta-analysis. The combined ES was 0.70 (95% CI = 0.54, 0.86) from the 34 ESs of published articles and 0.70 (95% CI = 0.35, 1.05) from the 8 ESs of unpublished studies. The 8 ESs from published abstracts had the lowest combined ES (ES = 0.53, 95% CI = 0.16, 0.90). These results implied no publication bias in the pedometer-based intervention studies used in this meta-analysis. The results of this meta-analysis provided sufficient evidence of the benefits of pedometer-based interventions to increase PA levels of people of different sex and age, and using different intervention lengths and strategies. Future research should focus on the analysis of the health outcomes of pedometer-based PA intervention comparing different moderators.

Conclusions

The cumulative evidence suggests that the use of pedometers has a moderate and positive effect on the increase of PA in intervention studies. The overall mean ES was 0.68, which translates to an average increase of 2,000 steps in the intervention group for all studies. The evidence suggests that the effects of pedometer use were similar across all age groups and intervention lengths. There were greater effects with females and intervention strategy of 10,000 steps/day as a step goal. This evidence can help in designing optimal pedometer-based interventions that maximize increases in PA participation.

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