A pedometer-based physical activity intervention may be effective in increasing daily step-count and improving subjective sleep quality among adolescents

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2013

BSc in Psychology

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Abstract - English

Background: Insufficient physical activity and poor subjective sleep quality are of major concern in adolescence as they are associated with various health problems. Pedometer interventions have been found to be effective among adults, but less is known about the efficacy of this type of intervention on adolescents' physical activity. Also, little is known about the effects of pedometer-based interventions on adolescent subjective sleep quality.
Aim: Examine the efficacy of a three-week pedometer-based intervention in increasing adolescents' average daily steps and subjective sleep quality. **Method:** Four Icelandic upper-secondary schools were randomized to a pedometer-based physical activity intervention group or a control group without pedometers. A total of 53 students at the age of 15-16 years provided valid step data. A three-day mean step-count and subjective sleep quality was assessed at baseline and follow-up. **Results:** When adjusted for baseline, an ANCOVA analysis revealed that the intervention group had a significantly higher average step-count (p = .03) compared to the control group measured at follow-up. Repeated measures analysis showed that subjective sleep quality improved significantly (p = .02) over time in the intervention group compared to the control group. **Conclusion**: Pedometer-based physical activity intervention can improve adolescents' daily step average as well as subjective sleep quality.

Keywords: Pedometer, physical activity, subjective sleep quality, adolescents

Abstract - Icelandic

Bakgrunnur: Ónæg líkamleg hreyfing og slök huglæg svefngæði ungmenna eru áhyggjuefni þar sem þau tengjast ýmsum heilsuvandamálum. Notkun skrefmæla í íhlutunum virðist gefa góða raun meðal fullorðinna, en minna er vitað um áhrif þessarar íhlutunar á líkamlega hreyfingu ungmenna. Einnig er lítið vitað um áhrif skrefmælatengdrar íhlutunar á huglæg svefngæði ungmenna. **Markmið:** Skoða áhrif þriggja vikna íhlutunar með skrefmæla á aukinn daglegann skrefafjölda og huglæg svefngæði ungmenna. **Aðferð:** Fjórir íslenskir menntaskólar voru með slembivali valin í íhlutunarhóp með skrefmæla til að meta líkamlega hreyfingu eða viðmiðunarhóp án skrefmæla. Fimmtíu og þrír nemendur á aldrinum 15-16 ára skiluðu inn nothæfum gögnum en meðaltals skrefafjöldi og huglæg svefngæði voru metin yfir 3 daga við grunnlínu og eftirfylgni. **Niðurstöður:** Mælingar voru aðlagaðar að grunnlínu og sýndi ANCOVA greining marktækt hærri meðal skrefafjölda (p = .03) hjá þátttakendum í íhlutunarhópi miðað við viðmiðunarhóp. Endurteknar mælingar sýndu einnig að huglæg svefngæði jukust marktækt (p = .02) í íhlutunarhópi miðað við viðmiðunarhóp eftir því sem á leið. **Niðurlag:** Notkun skrefmælaíhlutunar á líkamlega hreyfingu getur aukið daglegann skrefafjölda ungmenna sem og bætt huglæg svefngæði þeirra.

Lykilorð: skrefmælir, líkamleg hreyfing, huglæg svefngæði, ungmenni

Background

There is a descending trend in physical activity among adolescents in Europe including the Nordic countries such as Iceland (Eidsdóttir, Kristjánsson, Sigfúsdóttir, & Allegrante, 2008), with physical activity being significantly reduced by the time individuals enter upper-secondary school (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). For example, healthy children can be expected to acquire between 10-16.000 pedometer-determined steps/day but this steadily decreases to approximately 8000-9000 steps/day by the age of 18 (Tudor-Locke et al., 2011). More than half of the Icelandic adolescents do not achieve the recommended minimum of 60 minutes (e.g. Lýðheilsustöð, n.d.; Nader et al., 2008; Troiano et al., 2008) of daily physical activity (Eidsdóttir et al., 2008). This despite the fact that, the overall amount of sport club participation has steadily increased in Iceland (Eidsdóttir et al., 2008) and other Nordic countries such as Finland (Laakso, Telama, Nupponen, Rimpelä, & Pere, 2008). However, a longitudinal study conducted among Finnish youth tracked participation in organized sports in the same individuals from childhood into adolescence and found that there was a steep age-related decline between the ages 12-18 (Telama & Yang, 2000). Also, both Finnish and Icelandic data have reported an increased gap between vigorously active and inactive adolescents (Eidsdóttir et al., 2008; Telama & Yang, 2000), suggesting that physical activity patterns in adolescence may have become polarized with one group highly active and the other highly inactive.

This decrease in physical activity is of major concern as poor physical activity habits are associated with negative health outcomes (Arent & Landers, 2000; Hassmén, Koivula, & Uutela, 2000; Paluska & Schwenk, 2000; Sallis, Prochaska, & Taylor, 2000; Sigfusdottir, Asgeirsdottir, Sigurdsson, & Gudjonsson, 2011; Ströhle, 2009) such as depression (Hassmén et al., 2000), as well as with negative health behaviors such as smoking and poor diet (Pate, Heath, Dowda, & Trost, 1996). Furthermore, decreased physical activity and its associated health behaviors and outcomes may not be restricted merely to the adolescent years but may also be tracked into adulthood (Dregan & Armstrong, 2010; Hallal, Victora, Azevedo, & Wells, 2006; Janz, Dawson, & Mahoney, 2000; Von Ah, Ebert, Ngamvitroj, Park, & Kang, 2004). Therefore it is of upmost importance to design effective strategies to promote physical activity during the adolescent years.

A recent focus in public health has involved promoting moderate lifestyle or life-span physical activity (e.g. walking behavior), rather than physical fitness through exercise (Biddle, Gorely, & Stensel, 2004; Lubans, Morgan, & Tudor-Locke, 2009). The intriguing aspect of this focus is that the physical activity promoted (e.g. walking) is cost-free, convenient even for the most sedentary individuals, easily incorporated to daily life (Choi, Pak, & Choi, 2007) and can be sustained throughout the lifespan (Ogilvie et al., 2007). Furthermore, promoting moderate physical activity may lead to increased fitness or perception of fitness (Bjørgaas et al., 2005; Janssen & LeBlanc, 2010) and thus potentially function as a stepping-stone for further improvements in physical activity.

One promising strategy for promoting moderate-intensity physical activity is the use of pedometers. A major strength of pedometers is that they provide motivation to move through awareness of daily steps, while simultaneously functioning as a measurement tool for physical activity (Gardner & Campagna, 2011). Also, pedometer interventions are relatively low-cost and easy-to-execute and have shown to be effective in increasing physical activity within both genders, in children, adults and older adults (Kang, Marshall, Barreira, & Lee, 2009). However, less is known about the effectiveness of pedometer-based interventions among adolescent populations (Lubans et al., 2009).

In a study by Lubans, Morgan, Callister, & Collins (2009) it was found that adolescents in a 10-week pedometer-based physical activity intervention group increased their daily step average by approximately 1000 steps. Furthermore, the increase in the intervention group was significant for both genders over time as compared to the control group. Further evidence for the efficacy of pedometer-interventions among adolescents comes from a systematic review by Lubans et al. (2009), who found that 12 out of 14 studies reported significant positive effects of pedometer-based interventions. However, there was a significant difference in the observed effect depending on sample characteristics, assessment methods and study design. Also, there is a discrepancy about which components within a pedometer intervention are the most effective in increasing physical activity. For example, Zizzi et al. (2006) found no significant step-mean difference between a step-goal and no-goal group at follow-up assessment. Lubans et al. (2009) suggested that this may have been due to the fact that the step-goal group did not receive feedback about whether or not they had met their weekly step goals. As reviewed by Lubans and colleagues, vital elements to the effectiveness of pedometer interventions may be setting step goals and receiving feedback about whether or not these step goals are met, as well as the use of step diaries.

Poor subjective sleep quality is a common complaint among adolescents (Gradisar, Gardner, & Dohnt, 2011; Vignau et al., 1997) and is related to a wide variety of negative health (Pilcher, Ginter, & Sadowsky, 1997; Wong & Brower, 2012) and behavioral outcomes, such as decreased academic performance and daytime functioning (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010; Warner, Murray, & Meyer, 2008). Evidence from cross-sectional studies indicate that physically active adolescents may have more favorable sleep quality than those with more sedentary activity habits (Brand et al., 2010; Brand, Beck, Gerber, Hatzinger, & Holsboer-Trachsler, 2009; Tynjälä, Kannas, Levälahti, & Välimaa, 1999). However, to-date little is known about the efficacy of physical activity interventions in improving adolescents' subjective sleep quality. A randomized controlled trial by Kalak et al. (in press) found that a three-week, daily running intervention improved subjective sleep quality in adolescents in the intervention condition, but not in the control condition. This limited evidence suggests that promoting vigorous physical activity (e.g. running) may improve adolescents' subjective sleep quality. However, the question remains whether or not promoting moderate-intensity physical activity through pedometer interventions can improve adolescents' subjective sleep quality.

The main aim of this study is to examine the effectiveness of a three-week pedometer-based physical activity intervention on a sample of Icelandic adolescents in their first year of upper-secondary school. Based on the literature reviewed it is hypothesized that the intervention group will improve their steps significantly compared to the control group. Due to the lack of causal evidence, an exploratory hypothesis is set forth to explore the potential positive effects of a pedometer-based intervention on adolescents subjective sleep quality.

Methods

Participants

A total of 84 Icelandic students ages 15 and 16 from four upper-secondary schools in the Capital region were initially sampled. From each school one class was randomly selected and participants in the selected class were introduced and recruited to the study. In order to be included in the final analyses participants had to provide a minimum of two days of step-count data, both during baseline and follow-up measurements. A total of 53 (control n = 27, 65.4% female and intervention n = 26, 56.0 % female) participants provided step-counts sufficient to meet the inclusion criteria (63% of the initial sample). Participants that were randomized to intervention group also had to have a mobile phone in order to be included in the sample. No participants were excluded based on this criterion.

Procedure

Four schools in the Capital region in Iceland were chosen for the study and from each school one first-year class was randomly selected. Following the initial selection process the study was introduced during school hours to each class (i.e. school) independently. Participants were informed that they would receive two tickets to the cinema as a compensation for their participation and successful completion of the study. Students willing to participate received two copies of a written inform consent; one that they kept for themselves and another that was signed by a parent or guardian and returned to the research team at the beginning of the baseline assessment.

After the initial introductory meeting, schools were randomized into an intervention group with pedometers or a control group without pedometers. The baseline assessment was conducted in the facilities of each respective school. First, participants answered a questionnaire which took approximately 40 minutes to complete. Second, after finishing the questionnaire participants' stride length was measured and entered into the pedometer. Pedometers were then sealed and handed to the participant. Third, participants received a visual demonstration and written instructions of how to wear and handle the pedometer. Participants were encouraged to maintain normal physical activity habits and wear the pedometer for a minimum of 8 hours per day for three consecutive weekdays. By the end of the baseline period, participants returned their pedometers to the school's main office.

The following week the intervention group received unsealed pedometers and a daily step diary. The step diary was an A-4 sized compendium with information about the intervention and instructions about the wear and operation of the pedometers as well as designated areas for each day for the registration of daily steps. The participants were given a short motivational message and were encouraged to aim for 8.000-10.000 steps per day. Thus, participants were encouraged to engage in moderate physical activities (Tudor-Locke

& Bassett, 2004), such as going out for a brisk walk or to take the stairs instead of an elevator when possible. Participants were asked only to report step-counts for weekdays, thus weekend step-counts were not included in the analyses. Participants received credit on their mobile phones so that they were able to report their daily step-count via text message before going to bed. This was done in order to remind participants to keep track of their steps and maintain their daily step diaries. Participants also received a text message in the morning, reminding them to wear the pedometer.

After the three-week intervention period, the intervention group returned their pedometers. The data registered on the pedometers were compared to the self-reported (i.e. text messages) steps and corrected if the participant had not reported or reported invalid step-counts through text messages. The following week, follow–up assessment was conducted with all study participants and these procedures were identical to those conducted at baseline.

Design and measures

Study design was a randomized control trial with one control group without pedometers and one intervention group with pedometers.

Physical activity was assessed by Yamax CW-701 pedometers (Yamasa Tokei Keiki CO., LTD. Japan), which have shown to be one of the most accurate and reliable pedometer models available (Schneider, Crouter, & Bassett, 2004; Schneider, Crouter, Lukajic, & Bassett Jr, 2003). The main outcome measure for physical activity was a three-day step-count mean assessed at follow-up. According to Tudor-Locke et al. (2005) a one-day measurement is not acceptable, but two-days or any three-day mean is sufficient to reliably estimate an individual's average steps/day value. From the total sample 13 participants (control = 6, intervention = 7) at baseline and 15 participants (control = 9, intervention = 6) at follow-up provided only two full weekdays of valid step-counts. For these participants a two-day mean step-count was calculated, whereas a three-day mean was used with the majority of the sample.

Subjective sleep measures. Dimensions of sleep that were evaluated to reflect subjective sleep quality in the most parsimonious way were selected. Subjective sleep quality (SSQ) was measured by a summed score of four individual items that have been prevalent in subjective sleep quality studies; sleep onset latency (SOL), nightly awakenings (NA), sleep quality in general (SQG) and sleep sufficiency (SS). (Buysse et al., 1989; Chung, Kan, & Yeung, 2011; Gillberg, Keklund, Axelsson, & Akerstedt, 1996; Keklund & Akerstedt, 1997; Lewandowski, Toliver-Sokol, & Palermo, 2011; Tynjälä, Kannas, Levälahti, & Välimaa, 1999; Warner, Murray, & Meyer, 2008).

The four items assessed participants' evaluations of sleep in the past three weeks. The first item (SOL), "*how long did it usually take you to fall asleep?*" was answered on a five point scale ranging from "*it only took me a few minutes*" to "*it took me more than three hours or I did not fall asleep*". The second item (NA), "*on average, how often did you usually wake up during the night?*" was answered on a four point scale ranging from "*never*" to "*more than three times*". A fifth answer key was also provided where participants could answer "*I do not know*" and this was scored as a missing value. The third item (SQG), "*How would you evaluate your sleep quality in general*" was scored on a three point scale; "*good*", "*average*" or "*poor*". The final item (SS), "*How often did you receive sufficient sleep?*" was scored on a five point scale ranging from "*always*" to "*never*". All four items were summed to provide a global score with a minimum possible score of 4 and maximum of 17, where higher scores represented better sleep quality. Cronbach's reliability coefficient for the SSQ-scale at baseline was $\alpha = .57$ and at follow-up $\alpha = .65$.

Potential control variables were assessed by questionnaires at baseline including questions concerning family structure and economic status, parental education level, mental and physical health, physical fitness, frequency of physical activity in school, leisure time, and organized sports.

Data and statistical analyses

Before data analysis was executed, daily step-counts below the suggested basal-level of steps or 2500 steps/day (Tudor-Locke, Craig, Thyfault, & Spence, 2012) were filtered out from the data. Mean step-counts were calculated for both baseline and follow-up and participants that did not provide a minimum of two days of valid baseline (n = 9) or follow-up (n = 25) step data were excluded from the main analyses. For sleep quality measures, items were reversed so that higher scores represented better sleep quality. Furthermore, participants with missing values on one or more of the four individual sleep items were excluded from subjective sleep quality analyses.

All statistical analyses were performed with IBM statistic, SPSS version 20. Group differences in potential control variables at baseline were assessed by Fischer’s exact test, Pearson’s chi-square and independent samples t-test.

An analysis of covariance (ANCOVA) controlling for baseline was conducted to analyze group differences in mean steps at follow-up assessment. Repeated measures analysis of variance (ANOVA) was utilized for subjective sleep quality analyses. In all analyses the level of significance was set at $p < .05$.

Ethical issues

The study was guided by strict methodological protocols and all aspects of data collection were approved by the Icelandic human subjects review committee. Parents of all participants were contacted and informed about the study. Parental approval was acquired from each participant prior to the intervention through a written inform consent.

Results

Excluded participants

The majority (74.2 %) of the participants that did not provide sufficient step-count data were males. Within the control group 19 (41.3%) and intervention group 12 (31.6%) participants did not provide sufficient step-data in order to be included in the final analyses. The excluded participants did not significantly differ from the included participants in potential control variables.

Sample characteristics

All participants were between 15 and 16 years old, born in the same year. Within the total sample, 49.0 % took part in organized sports four times or more per week and 31.4 % never or almost never participated. Consecutively, 7.5 % and 11.3 % of the adolescents participated in sport club physical activity 2 or 3 times per week, respectively. Daily step-count means showed that the majority (43.3%) accumulated on average between 5000-7499 and 32.1 % between 7500-9999 steps per day.

Potential control variables are presented separately for each group in table 1. Participants in the control and intervention group did not differ significantly in any of the potential control variables.

Table 1. Potential Control Variables Within Groups and Between Groups Differences

Control variables	Control %	Intervention %	*p*
Gender (% female)	65.4	56.0	.57[a]
Father's education (% University)	52.0	58.3	.49[b]
Mother's education(% University)	68.0	66.7	.79[b]
Family structure (% Live with both parents)	88.0	64.0	.14[b]
Family economic status (% Average or higher)	100.0	88.0	.13[b]
Mental health status (% good or very good)	88.0	84.0	.91[b]
Physical health status (% good or very good)	84.0	84.0	.74[b]
Physical fitness (% good or very good)	69.2	72.0	.97[b]
Engage in physical education classes (% 2-3 times/week)	53.8	88.0	.46[c]
Compete or practice with a sport club (% 4 times or more/week)	42.3	56.0	.40[c]
Physical activity excluding school and sport clubs (% one time or less/week)	57.7	68.0	.26[c]
Physically exert yourself (increased heart rate or sweating) (% 4 times or more/week)	61.5	68.0	.38[c]
Daily caffeine consumption (% low)	52.0	70.8	.44[c]

Note. [a]*p*-value is based on Fisher's exact test for dichotomized variables between treatment groups. [b]*p*-value is based on Pearson's chi-square test between treatment groups. [c]*p*-value based on independent samples t-test between treatment groups.

Outcome measures

Baseline values for the two main outcome measures separated by group are presented in table 2. There was a significant baseline difference in step-count mean between the control (M = 8658.57, SD = 2335.35) and the intervention group (M = 7128.29, SD = 2281.61), $t(51) = 2.41$, $p < .05$. There were no baseline differences between the groups in other measures.

Table 2. Baseline Values for Step-count Means and Subjective Sleep Quality Measures Separated by Group

	Control		Intervention		*p*
Baseline measures	n	%	n	%	
Three-day step-count mean	27		26		.02[a]
<5000		7.4		7.7	
5000-7499		51.9		42.3	
7500-9999		29.6		19.2	
10000-12499		3.7		23.1	
≥ 12500		7.4		7.7	
Sleep onset latency (usually)	26		25		.08[b]
Only a few minutes		46.2		24.0	
< 30 minutes		42.3		40.0	
30- 60 minutes		3.8		32.0	
> 60 minutes		3.8		0.0	
Nightly awakenings (usually)	26		25		.48[b]
Never		50.0		32.0	
Once		23.1		32.0	
2-3 times		15.4		28.0	
> 3 times		11.5		8.0	
Sleep quality in general	26		24		.60[b]
Good		57.7		66.7	
Average		30.8		29.2	
Poor		11.5		4.2	
Sufficient sleep per night	26		24		.48[b]
Always		23.1		16.7	
Usually		46.2		33.3	
Sometimes		15.4		33.3	
Rarely or never		15.4		16.7	
Sleep quality global score* (4-17)	26		24		.31[a]
4-9		3.8		8.3	
10-11		23.1		25.0	
12-13		19.2		25.0	
14-15		23.1		25.0	
16-17		30.8		16.7	

Note. Individual items assessed subjective sleep over the past 3-weeks. [a]*p*-value is based on independent samples t-test between treatment groups. [b]*p*-value is based on Pearson's chi-square test between treatment groups across categories .* Higher score represents better subjective sleep quality.

An analysis of covariance (ANCOVA), controlling for baseline revealed that at the follow-up assessment the intervention group had a significantly higher mean step-count (M= 8384.13, SD = 2904.05) than the control group (M = 7666.48, SD = 2854.03), $F(1, 50) = 5.16$, $p = .027$, Partial Eta Squared = .093. To explore the effects of gender, gender and the interaction term (gender by group) were included into the model but neither were significant ($p > .05$).

Subjective sleep quality between groups was analyzed with repeated measures analysis of variance. The main effect for time was non-significant, F(1, 43) = .69, *p* = .41, Partial Eta Squared = .016. However, there was a significant time by group interaction effect, F(1, 43) = 5.81, *p* = .020, Partial Eta Squared = .119, which is illustrated in figure 1.

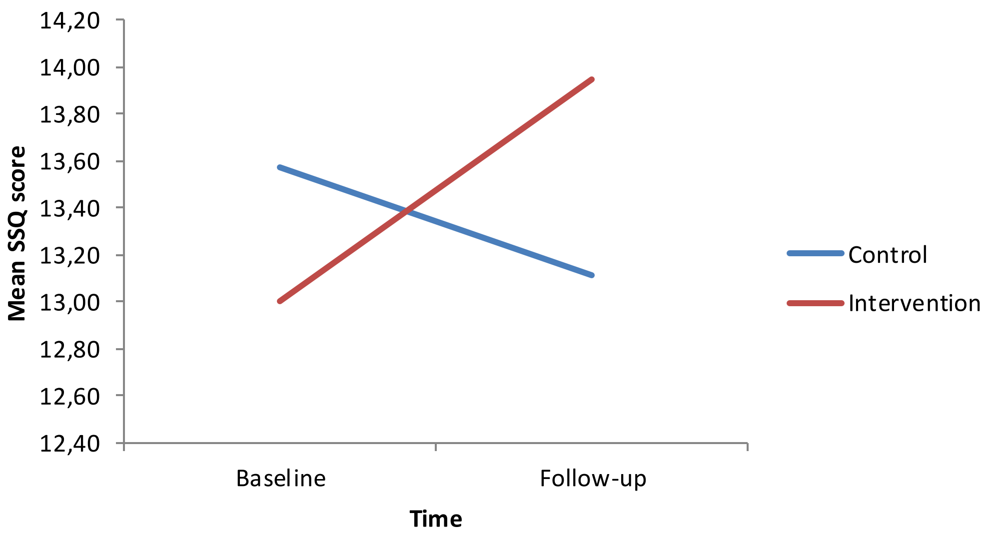

Figure 1. Repeated Measures ANOVA With Interaction Between Group and Time in Subjective Sleep Quality (SSQ)

Simple effect analyses of the within subject factors revealed that there was a significant increase in subjective sleep quality in the intervention group, F(1, 18) = 4.59, *p* = .046, Partial Eta Squared = .203, while there was no significant change over time in the control group, F(1, 25) = 1.47, *p* = .24, Partial Eta Squared = .055.

There was a close to significant baseline difference between the groups in subjective sleep onset latency (*p* = .08). An ANCOVA analysis was executed controlling for potential baseline differences and revealed a significantly higher mean score for the intervention group compared to the control group at follow-up assessment, F(1, 44) = 4.90, p = .03, Partial Eta

Squared = .100. The remaining sleep items did not reach statistical significance between the groups.

Discussion

The present study examined the effectiveness of promoting moderate-intensity physical activity among healthy adolescents through a pedometer-based physical activity intervention and explored the possible effects of the intervention on adolescents subjective sleep quality. Consistent with study hypothesis, the intervention group had a higher step-count average compared to the control group at the end of the intervention. Also, the exploratory hypothesis was supported as subjective sleep quality within the intervention group was significantly improved over time but not in the control group. Self-reported physical activity habits within the study sample were in agreement with studies suggesting that adolescent sport activities have become polarized between high and low physically active adolescents (e.g. Eidsdóttir et al., 2008; Telama & Yang, 2000).

The finding that the pedometer-based intervention improved daily step-count is consistent with Lubans et al. (2009) who found that 12 out of 14 pedometer-based interventions were effective in increasing steps among adolescents. The observed increase of approximately 1000 steps/day found by Lubans, Collins, et al., (2009) is similar to the increase of approximately 1200 steps/day found in the present study. Although gender was not a main focus in this study, possible differential effect of the intervention between genders was evaluated; however no such effect was found, again being consistent with findings by Lubans, Collins, et al., (2009). Unlike the control group, the participants in the intervention group wore an open pedometer for three weeks. Also, they were given a step goal, registered their accumulated steps in step diaries, and received daily reminders about the use of pedometers in form of text messages. Thus consistent with the literature reviewed in Lubans et al. (2009), the key to the effectiveness of pedometer interventions may be the use of motivational tools such as step goals and daily steps diaries in parallel to the wear of a pedometer. It should however be noted that a study by Zizzi et al. (2006) did not find significant differences between a step-goal group and no-goal group. Lubans et al. (2009) suggested that this may have been due to the fact that the step-goal group did not receive feedback about whether or not they had met their weekly step goals. The same limitation however applied to the present study, yet the daily step average was significantly higher in the intervention group compared to the control group at follow-up assessment. An alternative explanation may have been that, unlike the present study, randomization by Zizzi and colleagues was conducted on the level of participants. Thus, there were two different treatment groups within the same school. This could have resulted in cross-contamination (Schofield, Mummery, & Schofield, 2005) and thus interfered with finding significant differences between groups. Considering the discrepancy about the effectiveness of different components in a pedometer intervention, future studies should use multiple treatment groups in order to tease apart the most effective components.

Due to baseline differences and only one follow-up assessment, it was not possible to assess improvements in step-counts between the groups over time. Why was there a baseline difference between the groups, despite strict randomization procedures? One explanation may have been that the individual schools differed in some specific characteristics. One such factor may have been differences in baseline reactivity to the introduction of pedometers. In their discussion Lubans, Collins, et al., (2009) mentioned possible inflation effects due to reactivity during the baseline assessment, where the novelty of wearing a pedometer may have positively influenced participants' activity habits. It is possible that the schools in the control group had a more pronounced reaction to the initial wear of a pedometer and thus had an inflated baseline mean step-count. If reactivity indeed was an issue, it would be reasonable to expect that this effect would dissipate and the step-count mean would regress back to a normal baseline value. Future studies should thus assess baseline values over two or more occasions in order to provide more accurate estimates of pedometer-determined steps at baseline.

The results from the present study showed that subjective sleep quality improved significantly over time in the intervention group compared to the control group, which is in line with the available cross-sectional evidence among adolescents (Brand et al., 2010, 2009; Tynjälä et al., 1999) and intervention studies conducted among adults (Buman, Hekler, Bliwise, & King, 2011; Chen, Liu, Huang, & Chiou, 2012; Gebhart, Erlacher, & Schredl, 2011; King, Oman, Brassington, Bliwise, & Haskell, 1997; Li et al., 2004). Also, the present study is consistent with the findings by Kalak et al. (in press), who found that a vigorous physical activity intervention in form of daily running for 30 minutes improved subjective sleep quality in the intervention group compared to the control group. Kalak and colleagues utilized a well validated instrument, the Insomnia Severity Index in their assessment of subjective sleep quality (Bastien, Vallières, & Morin, 2001; Chung et al., 2011; Morin, Belleville, Bélanger, & Ivers, 2011). This is a major strength compared to the present study which, although utilizing similar items, did not assess sleep quality with a validated sleep quality measure. Nevertheless unlike the present study, Kalak and colleagues did not assess physical activity objectively, thus complicating the inferences about the causal effects of physical activity on subjective sleep quality. Furthermore, there was a practical limitation to their study, as early morning running 5 times a week, for 30 minutes may not be appealing for low-active adolescents.

A more detailed analysis of the individual sleep-items revealed that sleep onset latency was the only item that significantly improved in the intervention group compared to the control group. This is in line with studies conducted among older adults, which have found that physical activity interventions may have a particularly marked positive effect on sleep onset latency (King et al., 1997; Li et al., 2004). When considering that the global sleep quality score was constructed of only four items, it is possible that improvements in subjective sleep quality in the intervention group were mediated by improvements in sleep onset latency.

The major strength of this study was that it utilized a randomized control trial methodology, thus providing much needed addition and support to the current empirical data. This study also had practical value by demonstrating that promoting moderate-intensity physical activity may be sufficient to increase adolescents' daily step-count. The practical value lies in the idea that moderate intensity physical activity may increase physical fitness and awareness of daily physical activity (Bjørgaas et al., 2005; Janssen & LeBlanc, 2010), and provide a more convenient alternative to vigorous physical activity among sedentary adolescents. Another major strength of the current study was that it explored the largely under-studied causal relationship between adolescent subjective sleep quality and physical activity.

There were also several limitations to the present study. Obvious limitations were a small sample size, short intervention duration, a single follow-up assessment and a relatively high attrition rate due to invalid or missing data. Hence, from the initial 84 participants only 53 (63%) provided adequate step-count data. However, there is some indication that similar "dropout" rates may be common among adolescents (Shimon & Petlichkoff, 2009) as well as children (Eisenmann, Laurson, Wickel, Gentile, & Walsh, 2007). Thus, this aspect of pedometer interventions among adolescent should be studied in more detail. The results from the present study suggested that attrition may be more of an issue among male than female participants, but this aspect should be studied further. Finally, although the present study promoted moderate-intensity physical activity it is unclear whether increases in steps in the intervention group were due to moderate or vigorous physical activity. Therefore, future studies should explore possible differences in the efficacy of promoting either moderate or vigorous physical activity and assess the type of activity that is increased by these different approaches.

Subjective sleep quality was assessed only by four items that were found prevalent in previous research. However, the low amount of items may have resulted in poor internal reliability of the subjective sleep quality scale with Cronbach's alpha .57 at baseline and .65 at follow-up. It is likely that a complex construct such as sleep quality may not be adequately assessed by only four items. This would be supported by the fact that other studies using only a few items have reporter similar reliability coefficients as observed in the present study. For example, a highly cited article by Tynjälä et al. (1999) assessed sleep quality with three items and reported an internal reliability of 0.66. Also, Warner et al. (2008) used a 6-item scale in their study and reported an internal reliability of .62. Furthermore, the scaling was different between items in the present study, thus using only a summed score may have limited the subjective sleep quality findings. Considering these limitations, the present results concerning subjective sleep quality should be interpreted with caution.

Despite its limitations, the present study offers added knowledge about the effectiveness of pedometer-based interventions among adolescents. Furthermore, the approach of the study was unique as it was designed to promote moderate-intensity activity, while including assessment of subjective sleep quality. Despite limitations in the assessment of subjective sleep quality, the present study is the first study that has specifically explored adolescents' subjective sleep quality in the context of pedometer-based interventions.

Conclusion

Evidence suggests that physical activity has become polarized among the adolescent populations, where one group of adolescents is highly active and the other remains sedentary. In order to prevent the gap from widening ever more, effective strategies that appeal to a wide range of adolescents should be designed. Based on previous studies and the findings in the present study pedometers may provide an effective strategy to tackle the challenges set by the declining trend of physical activity among adolescents. The effects of reactivity should be taken into account and possibly conduct two or more baseline measurements before initiating an intervention. Also, adherence to pedometer-interventions should be studied more in order to find effective solutions to maintain adolescents motivated throughout the study period. Future studies should emphasize larger scale studies with several treatment groups in order to tease apart the cause and effect relationships between different motivational tools and increase in daily steps. Furthermore, future studies should aim to look whether promoting vigorous or moderate physical activity differ in their efficacy in increasing physical activity as well as the type of physical activity that may be influenced, both in short and long-term. As subjective sleep quality improved in the intervention group future pedometer-based interventions should study this further and aim to assess subjective sleep quality more comprehensively. Also studies should add other health outcome measures in order to better map the influences of pedometer-based physical activity interventions among adolescents.

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