Original Paper

A Bit of Fit: Minimalist Intervention in Adolescents Based on a Physical Activity Tracker

Jeffrey Gaudet[1], MSc; François Gallant[1,2], BSc Kin; Mathieu Bélanger[1,2,3], PhD

[1]Centre de formation médicale du Nouveau-Brunswick, Moncton, NB, Canada

[2]Faculty of Medicine and Health Sciences, Université de Sherbrooke, Sherbrooke, NB, Canada

[3]Vitalité Health Network, Moncton, NB, Canada

Corresponding Author:
Mathieu Bélanger, PhD
Centre de formation médicale du Nouveau-Brunswick
18 Antonine Maillet street
Moncton, NB,
Canada
Phone: 1 506 863 2221
Fax: 1 506 863 2284
Email: mathieu.f.belanger@usherbrooke.ca

Abstract

Background: Only 5% of Canadian youth meet the recommended 60 minutes of moderate to vigorous physical activity (MVPA) per day, with leisure time being increasingly allocated to technology usage. Direct-to-consumer mHealth devices that promote physical activity, such as wrist-worn physical activity trackers, have features with potential appeal to youth.

Objective: The primary purpose of this study was to determine whether a minimalist physical activity tracker-based intervention would lead to an increase in physical activity in young adolescents. A secondary aim of this study was to assess change in physical activity across a 7-week intervention, as measured by the tracker.

Methods: Using a quasi-experimental crossover design, two groups of 23 young adolescents (aged 13-14 years) were randomly assigned to immediate intervention or delayed intervention. The intervention consisted of wearing a Fitbit-Charge-HR physical activity tracker over a 7-week period. Actical accelerometers were used to measure participants' levels of MVPA before and at the end of intervention periods for each group. Covariates such as age, sex, stage of change for physical activity behavior, and goal commitment were also measured.

Results: There was an increase in physical activity over the course of the study period, though it was not related to overall physical activity tracker use. An intervention response did, however, occur in a subset of participants. Specifically, exposure to the physical activity tracker was associated with an average daily increase in MVPA by more than 15 minutes (P=.01) among participants who reported being in the action and maintenance stages of behavior change in relation to participation in physical activity. Participants in the precontemplation, contemplation, and preparation stages of behavior change had no change in their level of MVPA (P=.81).

Conclusions: These results suggest that physical activity trackers may elicit improved physical activity related behavior in young adolescents demonstrating a readiness to be active. Future studies should seek to investigate if integrating physical activity trackers as part of more intensive interventions leads to greater increases in physical activity across different levels of stages of behavior change and if these changes can be sustained over longer periods of time.

Introduction

Despite the documented benefits of physical activity on the physical, psychological, and social well-being of young people [1,2], only 5% of Canadian youth between the ages of 12 and 17 meet the recommended guidelines of 60 minutes of moderate to vigorous physical activity (MVPA) per day [3]. This is worrisome as physical inactivity during youth has been shown

XSL•FO
RenderX

to track into adulthood [4] and lead to an increased risk for multiple chronic conditions [5]. The need to identify successful interventions aimed at increasing physical activity among youth is warranted, given that results from previous intervention studies have shown room for improvement [6].

As youth are allocating increasingly more time to technology [7], technological platforms have concurrently gained popularity as a means to target health behavior [8]. mHealth technologies, including wearable physical activity trackers and mobile apps could be promising components of interventions aimed at reducing physical inactivity [9,10]. Past research has shown that interventions centered on the use of simple wearable devices, such as uniaxial pedometers, can lead to increases in physical activity participation and reductions in body mass index and blood pressure [11,12]. However, the strongest intervention effects have generally occurred when technological platforms were combined with at least one theoretically-based behavior change component [11]. Given that the newest accelerometer-based physical activity tracking devices are equipped with user-friendly features that relate to behavior change theory such as goal setting, review of past goals, and frequent feedback, it is possible that their effects on adhering to healthy physical activity levels is stronger [13]. The effects of such devices may also be more important in some sub-groups, for example, based on the stages of readiness to change. Past research has suggested that there is greater potential for intervention effectiveness in increasing physical activity among people who demonstrate the highest levels of readiness to get active as compared with those closed to the idea of being more physically active [14,15].

The use of commercially available accelerometer-based physical activity trackers as a means to target behavior change has been linked to increases in daily steps and time spent in MVPA in various adult populations [16-18]. Studies involving youth have,

however, been limited to patients living with disease [19-21], eight-year-old children [22], and urban youth living in an under-resourced community [23]. Thus, the primary purpose of this study was to determine if a minimalist physical activity tracker-based intervention would lead to an increase in physical activity in young adolescents. Secondary aims of this study were to assess change in physical activity across a 7-week intervention, as measured by the physical activity tracker, and to assess differences in change in physical activity based on individuals' goal commitment and stage of behavior change.

Methods

Participants and Procedures

All students in the two Grade 8 (13-14 years old) classes in one school were invited to participate in this study. To participate, students had to obtain written informed consent from parents or legal guardians and provide assent as approved by the Centre Hospitalier de l'Université de Sherbrooke ethics committee. This study employed a quasi-experimental crossover design with a 7-week physical activity tracker-based physical activity intervention and a control period. Participants in one class (group A) were randomly assigned to the immediate intervention group and participants in the other class (group B) were assigned to the delayed intervention group (Figure 1). The crossover design was used to allow participants from both groups to have a chance to experiment with the physical activity tracker. This design also allowed controlling for individual-level covariates as participants served as their own control. Baseline measurements were obtained before the first week of intervention. Physical activity measurements for all participants were also obtained at the end of both intervention periods: weeks 7 and 14. This study took place between February and June, 2016.

Figure 1. Crossover design of the physical activity tracker-based intervention study.
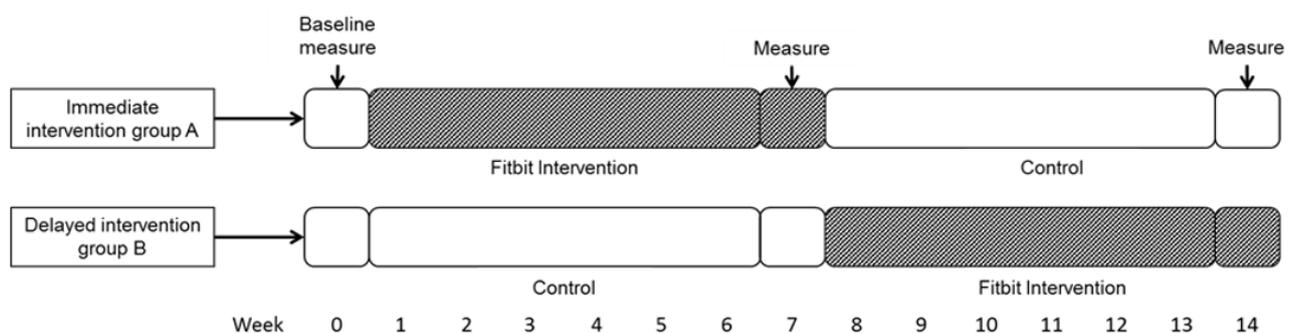
Intervention

The intervention focused on increasing physical activity via self-monitoring and self-regulation. During the intervention period, each participant was provided a wrist-worn physical activity tracker (Fitbit, model Charge HR; FitBit Inc. San Francisco, USA) that was equipped with a small screen displaying real-time summary data for steps, heart rate, distance, calories, and stairs climbed. Physical activity intensity minutes and temporal patterns were also available to participants through

the accompanying Web-based Fitbit user account. Individual Fitbit user accounts were prepared by the study coordinator for each participant before the distribution of the devices. The study coordinator was also responsible for demonstrating how to use the Fitbit device and Web-based Fitbit user account. The intervention was similar to that used in previous studies [10,16] and was based on Behavior Change Technique research [24]. Empirical research shows that self-monitoring, in combination with at least one other self-regulation skill, can lead to positive physical activity related behavior change [24]. An individualized

goal that can be tracked using measures provided by the physical activity tracker was set by each participant, following a brief researcher-led presentation of the SMART (specific, measurable, attainable, realistic, and timely) principles of goal-setting [25]. Beyond receiving physical activity trackers during the intervention period and being asked to select a goal, participants did not receive other interventions. During the control period, participants received no intervention.

Measures

Actical accelerometers (Philips - Respironics, Oregon, USA) were worn on the hip for seven days at baseline, week 7, and week 14. This lightweight omnidirectional accelerometer has been validated as an objective measure of physical activity in youth aged 10 to 15 years [26]. Accelerometer data were recorded in 15-second intervals, then cleaned and managed using procedures recommended by Statistics Canada [27] through a series of publicly available SAS codes adapted for this type of study [28]. Time spent in different physical activity intensities were determined by using cut-points established in previous research involving Actical accelerometers in children [29]. Sedentary activity corresponded to count values below 100, light physical activity to counts between 100 and 1500, moderate physical activity to counts between 1500 and 6500, and vigorous physical activity to counts greater than 6500. Only data for valid days, defined as 10 hours or more of wear time, were retained for analyses. Daily averages for MVPA were calculated from valid days.

Using the Fitabase analytics system (Small Steps Labs, San Diego, CA, USA), data from all physical activity trackers were remotely collected and aggregated whenever data were transmitted to users' personal Fitbit dashboards. Data captured included heart rate, daily steps, and minutes of intensity-specific physical activity. Wear time was calculated by subtracting non-wear time from 24 hours and non-wear time was defined as any interval with at least 60 consecutive seconds of zero recording of heart rate. As heart rate was recorded at variable time periods by the physical activity tracker, allowing for 60 consecutive seconds of zero recording of heart rate was sufficient to distinguish non-wear from wear time. Indeed, identification of valid days remained stable across use of higher thresholds, for example 5, 15, 30, and 60 minutes, whereas significant information was lost with a threshold set under 60 seconds.

A baseline questionnaire was used to collect information regarding age, sex, stage of change for physical activity behavior, and goal commitment. Specifically, participants indicated whether they participated in at least 60 minutes of physical activity per day, using an item corresponding to the five stages of behavior change (precontemplation, "No, I do not participate in physical activity and I do not intend to in the next 6 months;" contemplation, "No, I do not participate in physical activity regularly but I intend to in the next 6 months;" preparation, "No, I do not participate in physical activity regularly but I intend to in the next 30 days;" action, "Yes, I have been participating in physical activity regularly, but for less than 6 months;" maintenance, "Yes, I have been

participating in physical activity regularly for more than 6 months") [30,31]. For analyses, these five stages of behavior change were grouped into two categories representing adoption (ie, action and maintenance) and preadoption (ie, precontemplation, contemplation, and preparation) as done by De Bourdeaudhuij et al [32]. Goal commitment, defined as determination to attain an objective, was assessed using a five-item scale refined and validated by Klein et al [33]. In this scale, participants indicated their level of commitment to the personal goal they had set with the following items using a 5-point Likert scale: (1) It's hard to take this goal seriously; (2) Quite frankly, I don't care if I achieve this goal or not; (3) I am strongly committed to pursuing this goal; (4) It wouldn't take much to make me abandon this goal; (5) I think this is a good goal to shoot for. Items 1, 2, and 4 were reverse-scored before calculating a mean of the five items meant to represent the construct of goal commitment [33].

Statistical Power Calculation

Based on previous research, which showed that a similar Fitbit-based physical activity tracker intervention induced a 36% increase in MVPA (pre-post change mean=172, SD=83 to mean=234, SD=119), albeit in a sample of adult women [16], we estimated that 22 participants per group would provide 80% power with 95% CIs.

Data Analysis

Wilcoxon rank-sum tests were used to compare between group differences at baseline and following both intervention periods. Wilcoxon signed-rank tests were used to compare within group difference at different time points. A multiple linear regression model was used to assess pre-post change in physical activity while controlling for the effects of time, goal commitment, and stage of behavior change. Physical activity data, from both physical activity trackers and accelerometers, were adjusted for valid wear days. A valid wear day was defined as at least 10 hours of wear time. Repeated measures analysis and Tukey post-hoc tests were used to assess changes in physical activity tracker-measured physical activity throughout the intervention period. All analyses were conducted using SAS 9.4 (SAS Institute, Inc., Cary, North Carolina, USA).

Results

We recruited 46 of the 52 students eligible for this study. On average, the participants (52% girls, 24/46) were 13 years (SD=0.34) old and age and gender were distributed equally in both groups. There were no apparent or statistical (at Cronbach alpha<.05 with Fisher's exact test or independent *t* tests) differences in baseline characteristics between the two study groups (Table 1). At baseline, participants wore the accelerometer for an average of 13.0 (SD=1.3) hours per day and performed a mean of 35.5 (SD=19.0) minutes of MVPA per day. Accelerometer data were available for analyses for 43 participants at baseline, 32 at the end of the first intervention period (week 7), and 27 at the end of the second intervention period (week 14).

**Table 1.** Baseline characteristics of study participants.

Charactristics	Group A (n=23)	Group B (n=23)
Age in years, mean (SD)	13 (0.3)	13 (0.4)
Females, n (%)	12 (52)	12 (52)
Accelerometer Valid Days, mean (SD)	4.7 (1.7)	3.1 (2.1)
Accelerometer Wear Time in hours, mean (SD)	13.4 (1.2)	12.6 (1.3)
MVPA[a] in minutes, mean (SD)	34.7 (19.1)	36.2 (19.2)
Sedentary Time in minutes, mean (SD)	623.6 (82.6)	587.5 (67.1)
Goal commitment score from 1 to 5, mean (SD)	4.1 (0.6)	3.7 (0.9)
Stage of behavior change, n (%)		
Precontemplation	3 (13)	1 (4)
Contemplation	1 (4)	4 (17)
Preparation	2 (9)	4 (17)
Action	3 (13)	5 (22)
Maintenance	14 (61)	9 (38)

[a]MVPA: Moderate to vigorous physical activity.

In the main analysis, the multiple regression model showed no overall effect of wearing the physical activity tracker on MVPA levels; however, a positive effect of time was found ($P=.008$). However, relative to baseline, the first group to receive the physical activity tracker intervention, group A, increased MVPA by 10.9 minutes/day ($P=.03$) over the first 7-week period, whereas the increase in MVPA for the delayed intervention group, group B, corresponded to 3.7 minutes/day ($P=.56$) during the same period (Figure 2). During weeks 8 to 14, group B was exposed to the intervention and displayed an average increase of MVPA of 13.2 minutes/day ($P=.49$), while the increase in MVPA represented 10.3 minutes/day ($P=.64$) in group A for this second period. There was no significance between group differences at the baseline or at the 7 weeks or 14 weeks assessments.

Figure 2. Baseline to 14-week changes in objectively measured physical activity from Actical accelerometers (group A was exposed to Fitbit from week 1 to 7 and group B was exposed to Fitbit from week 8 to 14, and "a" indicates significant difference between pre and post measurements within group A: $P=.03$).
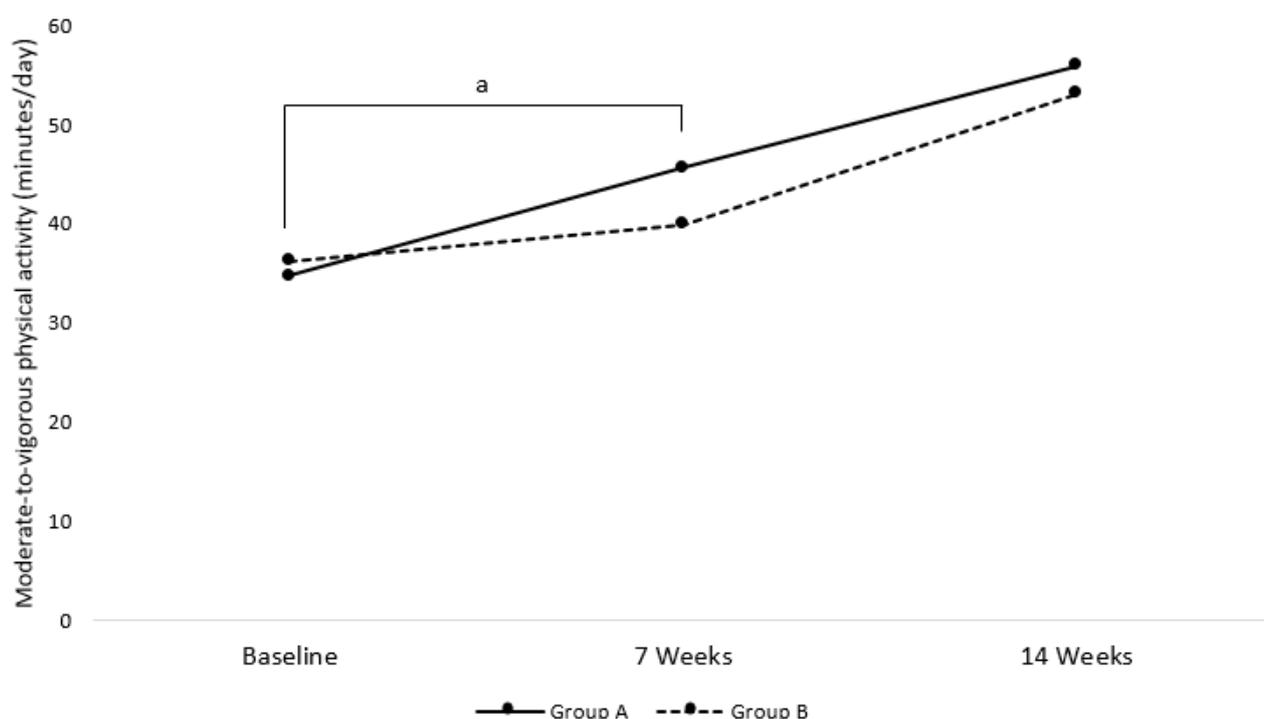
After combining the pre and post intervention scores of both groups (group A pre-intervention at week 0 and post-intervention at 7 weeks, and group B pre-intervention at 7 weeks and post-intervention at 14 weeks), Wilcoxon tests suggested that changes in mean MVPA were related to differences in stages of behavior change (Figure 3). Participants in the adoption stages had a significant increase in MVPA from pre to post-intervention (P=.01), whereas participants in the preadoption stages did not change (P=.81). Whereas both groups had similar levels of MVPA at the pre-intervention time point, the post-intervention difference between the adoption and preadoption group was over 23 minutes of MVPA (P=.02). Moreover, physical activity tracker data showed that participants in the adoption stages averaged 2900 more steps and 20 more minutes of daily physical activity during the intervention phase than those in the preadoption stages. No association was found between goal commitment and MVPA.

The median participant in this study wore the physical activity tracker device for at least 10 hours per day on 67.3% of intervention days (33/49). Mean valid wear period was 30 days (SD=13), with a range of 6 to 49 days. Tukey post-hoc investigations suggest that wearing of the physical activity tracker peaked during the first two weeks of the intervention period and then dropped abruptly at the third week (Figure 4). The mean number of valid wear days during weeks 3 to 7 was significantly lower than in the first two weeks (P<.001). Physical activity tracker measured physical activity time and step count also showed similar decline after week 2 (P=.04) and week 3 (P=.01), respectively.

Figure 3. Moderate-to-vigorous physical activity among preadoption (precontemplation, contemplation, and preparation) and adoption (action and maintenance) participants before and after a 7-week minimalist physical activity tracker intervention: data are means and standard deviations (SD), "a" indicates significant differences between pre and post measurements within group (P=.01) based on the Wilcoxon signed-rank test, and "b" indicates significant difference between groups at the post-intervention measurement (P=.02) based on the Wilcoxon sum-rank test.
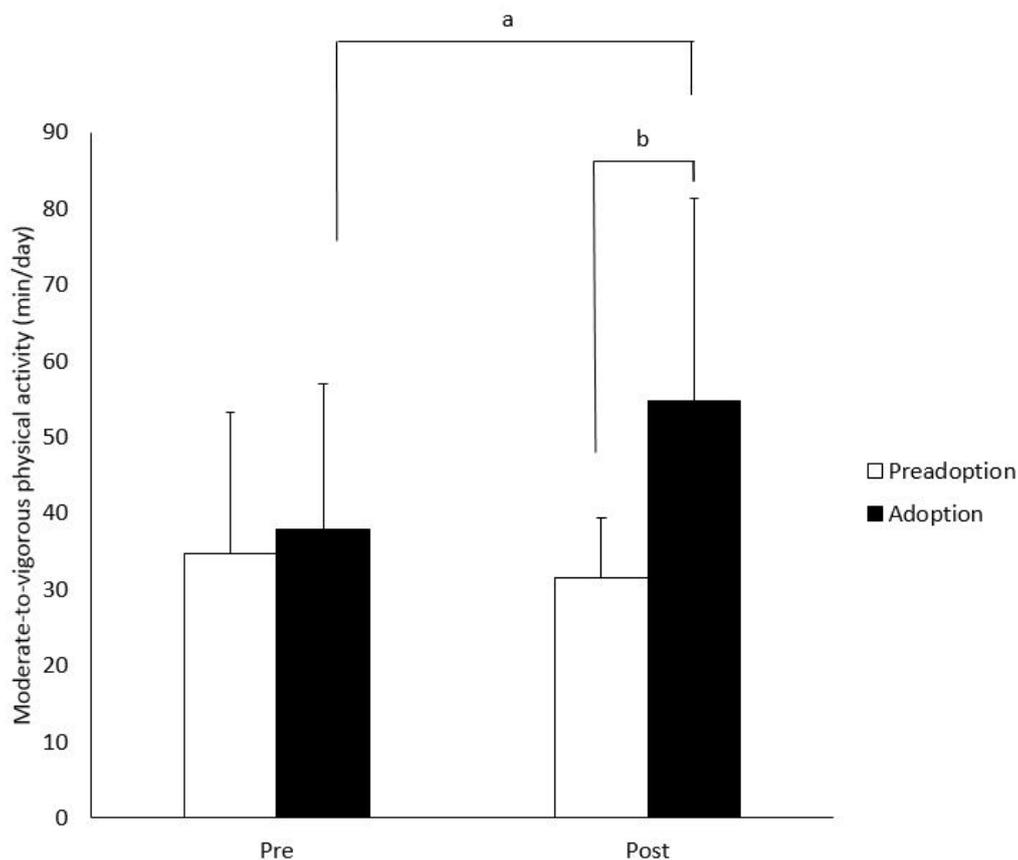
Figure 4. Changes in physical activity tracker measures during the 7-week intervention period (Valid days are defined as those with 10 hours or more of wear time, minutes of physical activity are Fitbit-defined minutes of "fairly to very active" physical activity, median and quartiles are represented in box plots, and "a" indicates significant differences from initial week).
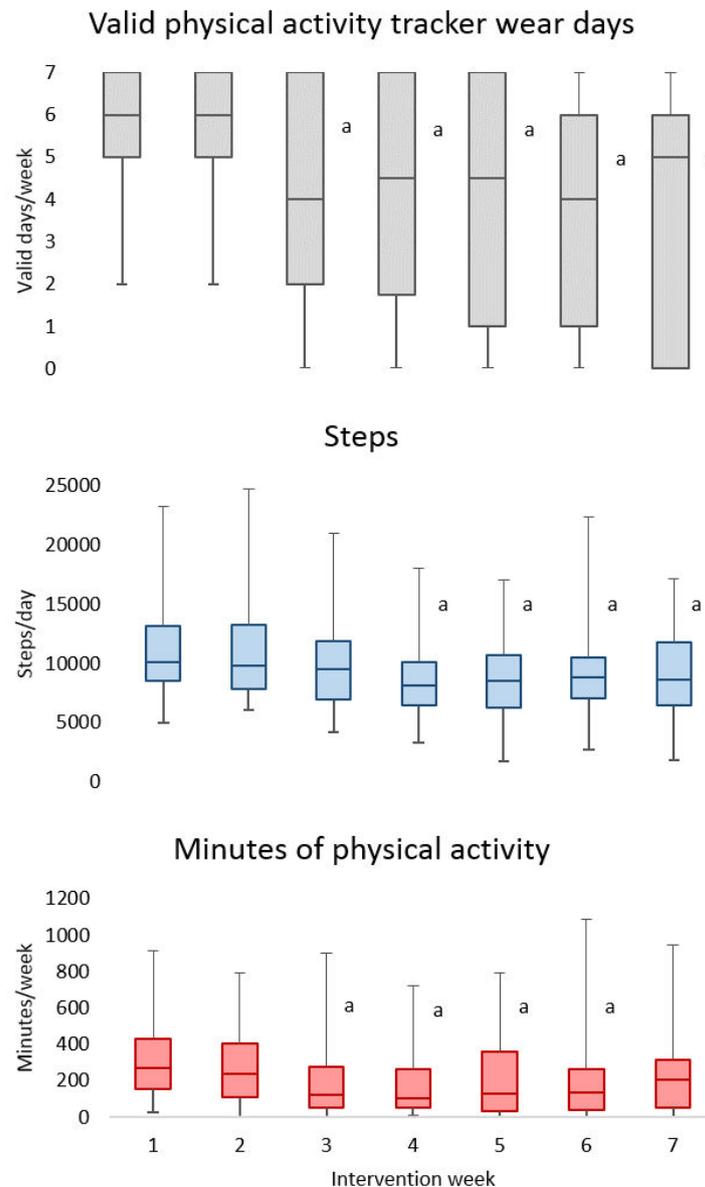
Discussion

Principal Findings

With little research to date on the effects of using direct-to-consumer mHealth trackers as behavior change tools, the current study sought to examine the effectiveness of using a minimalist physical activity tracker-based intervention as a means of encouraging increased physical activity in adolescents. Although the main results suggested no change in MVPA as a result of having been exposed to a physical activity tracker, secondary analyses suggest that the interventions may have had beneficial effects for some sub-groups. For example, an intervention response occurred in a subset of participants who reported being in the action and maintenance stages of behavior change (adopters) in relation to participation in physical activity. Whereas these participants increased their daily average of

MVPA by more than 15 minutes during the intervention period, those in the precontemplation, contemplation, and preparation stages (preadopters) had no change in their level of MVPA. This distinction manifested itself without the intervention being intentionally tailored to any specific stage of behavior change. Nevertheless, previous studies show that psychosocial determinants positively associated with physical activity generally increase across the stages of behavior change [32,34]. Adolescents in the adoption stages typically perceive fewer barriers, more benefits and have a better attitude and more self-efficacy in relation to physical activity participation [32]. Such underlying conditions likely predisposed these participants to be more receptive and to respond favorably to the exposure to a physical activity tracker. Although minimalist in nature, the introduction of a physical activity tracker may therefore represent a sufficient trigger for youth in the adoption stages to increase their level of physical activity. However, the

intervention was likely too simple to induce a behavior change among youth in the preadoption stages. Stage-specific intervention research suggests that in order to successfully motivate individuals in the preadoption stages, it is necessary to consider cognitive aspects of behavior change such as raising consciousness, social liberation, self-re-evaluation, self-liberation and counter-conditioning, helping relationships, and reward management [35,36].

The increase in physical activity among adopters may also be attributable to the fact that there was room for growth. Despite perceiving themselves as being active, objective measures suggested that participants in the adoption stages were not more active than those in the preadoption stages at baseline. This is similar to results from another study, which found little to no difference among levels of objectively measured MVPA of adolescents at different stages of behavior change [30]. Our results therefore point to the potential usefulness of assessing readiness to change before intervening. Although preadoption and adoption adolescents presenting similar objectively measured physical activity at baseline, the simple one-item questionnaire used to assess stages of change behavior change in this study correctly pre-identified participants who would best respond to the introduction of a minimalist physical activity tracker-based intervention.

This study was initiated during the middle of winter and extended to the end of spring. Thus, the start and end points of the study coincide with the typical periods of lowest and highest annual levels of physical activity in this age group, respectively [37-39]. This is noteworthy as the physical activity tracker-based intervention elicited an increase in physical activity during the study phase that corresponded to winter. Although it needs to be corroborated by other studies, it is possible that the introduction of physical activity trackers during this season could help some adolescents increase physical activity during the colder winter months. This is in support of findings from Dean et al [19] who observed, among a sample of adolescents with congenital heart disease, that wearing a physical activity tracker, as compared with not wearing one, was associated with a less abrupt decline of physical activity during winter months.

Continuous objective measurements obtained from physical activity trackers provided information suggesting that there was an acute effect of receiving the physical activity tracker. Specifically, compliance to wearing the physical activity tracker was at its highest during the first weeks of intervention. This would suggest that the device had a novelty effect, as demonstrated by others [23,40,41]. For instance, Shih et al [40] measured 50% attrition rates after the 2 week mark in a 6-week study in undergraduate students, while Schaefer et al [23], had only 2 participants (8%) use their physical activity trackers for a 4 month follow-up study. Beyond a decrease in compliance, it was noted that the average number of daily steps and minutes of physical activity were also at their peaks early in the intervention period. During the first three weeks, participants averaged between 9800 and 12,000 steps per day, which is close to the 10,000 to 12,000 steps per day recommended for this age group [42-44]. After the third week, however, this number declined to less than 9000 steps per day. Whereas normative data indicate that the majority of adolescents do not meet the

step count recommendation [44], our findings suggest that there may be potential for physical activity trackers to encourage adolescents to perform near recommended levels of physical activity, at least over a short period of time.

It is possible that accompanying the distribution of physical activity trackers with a more intensive intervention would have led to greater compliance in wearing the device and greater increases in physical activity. The participants in our study, nevertheless, wore physical activity trackers to a greater extent than adolescents from under-resourced communities in another study [23], but also considerably less than post-menopausal women in another study [16]. Direct comparison to wear time during intervention in other studies involving adolescents is not possible as this kind of information tends not to be reported [41,45].

Limitations

Limitations of this study need to be considered when interpreting the results. First, even though none of the participants was lost during the study, there was an unanticipated decline in compliance in wearing accelerometers at both post-intervention periods. This contributed to a loss of power to detect meaningful differences in physical activity, despite having initially recruited enough participants for adequate power. This drop in compliance may also have contributed to selection bias, wherein participants least likely to become more active did not wear the device at follow-up periods. Research is warranted to better understand adolescent engagement toward physical activity trackers to develop tailored interventions aimed at increasing compliance in this population [41,46]. Comparison between participants who completed all three evaluation periods and those who did not revealed no significant differences in physical activity level at baseline or distribution in stages of behavior change. Second, it needs to be considered that some activities were not measured because the accelerometer or physical activity tracker could not be worn (eg, swimming). Third, caution must be taken in interpreting physical activity tracker measured physical activity data as the proprietary algorithms used to calculate minutes of physical activity at different intensities are not publicly available. Fourth, although our results revealed a difference in intervention response between adolescents in the preadoption and adoptions stages, the small sample did not allow for in-depth analyses between each stage. Given the theoretical and empirical evidence of psychosocial and processes of change differences between each of the stages, future research with a larger sample is warranted to help elucidate which stages benefit the most from mHealth devices such as physical activity trackers. Future research should also assess whether similar physical activity tracker-based interventions lead to progressions in the stages of behavior change even among individuals who do not change their level of MVPA. Finally, although this study benefited from the strengths of randomization and crossover, having more randomization units in future studies would help attain group similarities even among unmeasured potentially confounding variables.

Conclusions

In summary, although no overall effect was found, the secondary results of this study suggest that there is potential value in using

physical activity trackers to increase physical activity among adolescents in adoption stages of behavior change related to participation in physical activity. Adolescents in the adoption stages of behavior change may benefit from simply gaining access to a direct-to-consumer mHealth device designed to track physical activity. Future research is needed to better understand what additional strategies could be paired with physical activity trackers to lead to improvements in physical activity levels of adolescents in all stages of behavior change. This study also has implications for research as it demonstrates the feasibility of continuously and objectively measuring physical activity during an intervention involving adolescents.

Authors' Contributions

MB and JG conceived the objectives of the analysis; JG collected and analyzed the data. All the authors participated in the interpretation of the data. JG and FG wrote the manuscript, while MB provided support.

Conflicts of Interest

None declared.

References

1. Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act 2010 May 11;7:40 [FREE Full text] [doi: 10.1186/1479-5868-7-40] [Medline: 20459784]

2. Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, et al. Evidence based physical activity for school-age youth. J Pediatr 2005 Jun;146(6):732-737. [doi: 10.1016/j.jpeds.2005.01.055] [Medline: 15973308]

3. StatCan. 2015. Directly measured physical activity of children and youth, 2012 and 2013 URL: http://www.statcan.gc.ca/pub/82-625-x/2015001/article/14136-eng.htm [accessed 2017-04-20] [WebCite Cache ID 6prtyzVDM]

4. Telama R. Tracking of physical activity from childhood to adulthood: a review. Obes Facts 2009;2(3):187-195. [doi: 10.1159/000222244] [Medline: 20054224]

5. Booth FW, Roberts CK, Laye MJ. Lack of exercise is a major cause of chronic diseases. Compr Physiol 2012 Apr;2(2):1143-1211 [FREE Full text] [doi: 10.1002/cphy.c110025] [Medline: 23798298]

6. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes (EarlyBird 54). BMJ 2012 Sep 27;345:e5888 [FREE Full text] [Medline: 23044984]

7. Rideout VJ, Foehr UG, Roberts DF. Kaiser Family Foundation. 2010 Jan. Generation M2: Media in the Lives of 8- to 18-Year-Olds URL: https://kaiserfamilyfoundation.files.wordpress.com/2013/04/8010.pdf [accessed 2017-04-20] [WebCite Cache ID 6prusl224]

8. Klasnja P, Pratt W. Healthcare in the pocket: mapping the space of mobile-phone health interventions. J Biomed Inform 2012 Feb;45(1):184-198 [FREE Full text] [doi: 10.1016/j.jbi.2011.08.017] [Medline: 21925288]

9. Bort-Roig J, Gilson ND, Puig-Ribera A, Contreras RS, Trost SG. Measuring and influencing physical activity with smartphone technology: a systematic review. Sports Med 2014 May;44(5):671-686. [doi: 10.1007/s40279-014-0142-5] [Medline: 24497157]

10. Cadmus-Bertram L, Marcus BH, Patterson RE, Parker BA, Morey BL. Use of the fitbit to measure adherence to a physical activity intervention among overweight or obese, postmenopausal women: self-monitoring trajectory during 16 weeks. JMIR Mhealth Uhealth 2015 Nov 19;3(4):e96 [FREE Full text] [doi: 10.2196/mhealth.4229] [Medline: 26586418]

11. Bravata DM, Smith-Spangler C, Sundaram V, Gienger AL, Lin N, Lewis R, et al. Using pedometers to increase physical activity and improve health: a systematic review. JAMA 2007 Nov 21;298(19):2296-2304. [doi: 10.1001/jama.298.19.2296] [Medline: 18029834]

12. Richardson CR, Newton TL, Abraham JJ, Sen A, Jimbo M, Swartz AM. A meta-analysis of pedometer-based walking interventions and weight loss. Ann Fam Med 2008;6(1):69-77 [FREE Full text] [doi: 10.1370/afm.761] [Medline: 18195317]

13. Lyons EJ, Lewis ZH, Mayrsohn BG, Rowland JL. Behavior change techniques implemented in electronic lifestyle activity monitors: a systematic content analysis. J Med Internet Res 2014 Aug 15;16(8):e192 [FREE Full text] [doi: 10.2196/jmir.3469] [Medline: 25131661]

14. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. Am J Health Promot 1997;12(1):38-48. [Medline: 10170434]

15. Spencer L, Adams TB, Malone S, Roy L, Yost E. Applying the transtheoretical model to exercise: a systematic and comprehensive review of the literature. Health Promot Pract 2006 Oct;7(4):428-443. [doi: 10.1177/1524839905278900] [Medline: 16840769]

16. Cadmus-Bertram LA, Marcus BH, Patterson RE, Parker BA, Morey BL. Randomized trial of a fitbit-based physical activity intervention for women. Am J Prev Med 2015 Sep;49(3):414-418. [doi: 10.1016/j.amepre.2015.01.020] [Medline: 26071863]

17. Finkelstein EA, Haaland BA, Bilger M, Sahasranaman A, Sloan RA, Nang EE, et al. Effectiveness of activity trackers with and without incentives to increase physical activity (TRIPPA): a randomised controlled trial. Lancet Diabetes Endocrinol 2016 Dec;4(12):983-995. [doi: 10.1016/S2213-8587(16)30284-4] [Medline: 27717766]

18.   Wang JB, Cadmus-Bertram LA, Natarajan L, White MM, Madanat H, Nichols JF, et al. Wearable sensor/device (Fitbit One) and SMS text-messaging prompts to increase physical activity in overweight and obese adults: a randomized controlled trial. Telemed J E Health 2015 Oct;21(10):782-792. [doi: 10.1089/tmj.2014.0176] [Medline: 26431257]

19.   Dean PH, Voss C, De Souza AM, Harris KC. Assessment, Assurance, and Actuation: the use of activity trackers to monitor physical activity in a pediatric population with congenital heart disease. Can J Cardiol 2016 Oct;32(10Suppl1):S130-S131. [doi: 10.1016/j.cjca.2016.07.194]

20.   Hooke MC, Gilchrist L, Tanner L, Hart N, Withycombe JS. Use of a fitness tracker to promote physical activity in children with acute Lymphoblastic Leukemia. Pediatr Blood Cancer 2016 Apr;63(4):684-689. [doi: 10.1002/pbc.25860] [Medline: 26756736]

21.   Jacobsen RM, Ginde S, Mussatto K, Neubauer J, Earing M, Danduran M. Can a home-based cardiac physical activity program improve the physical function quality of life in children with Fontan circulation? Congenit Heart Dis 2016;11(2):175-182. [doi: 10.1111/chd.12330] [Medline: 26879633]

22.   Hayes LB, Van Camp CM. Increasing physical activity of children during school recess. J Appl Behav Anal 2015 Sep;48(3):690-695. [doi: 10.1002/jaba.222] [Medline: 26119136]

23.   Schaefer SE, Ching CC, Breen H, German JB. Wearing, thinking, and moving: testing the feasibility of fitness tracking with urban youth. American Journal of Health Education 2016 Jan 08;47(1):8-16. [doi: 10.1080/19325037.2015.1111174]

24.   Michie S, Abraham C, Whittington C, McAteer J, Gupta S. Effective techniques in healthy eating and physical activity interventions: a meta-regression. Health Psychol 2009 Nov;28(6):690-701. [doi: 10.1037/a0016136] [Medline: 19916637]

25.   Johnson C, Moore E, Thornton M. A SMART approach to motivating students in secondary physical education. Journal of Physical Education, Recreation & Dance 2014 Mar 27;85(4):42-44. [doi: 10.1080/07303084.2014.884839]

26.   Romanzini M, Petroski EL, Ohara D, Dourado AC, Reichert FF. Calibration of ActiGraph GT3X, Actical and RT3 accelerometers in adolescents. Eur J Sport Sci 2014;14(1):91-99. [doi: 10.1080/17461391.2012.732614] [Medline: 24533499]

27.   Colley R, Connor Gorber S, Tremblay MS. Quality control and data reduction procedures for accelerometry-derived measures of physical activity. Health Rep 2010 Mar;21(1):63-69 [FREE Full text] [Medline: 20426228]

28.   Boudreau J, Bélanger M. mathieubelanger.recherche. 2015. SAS Code for Accelerometer Data Cleaning and Management Version 1.3 URL: http://mathieubelanger.recherche.usherbrooke.ca/Files/Other/UserManual_BoudreauBelanger%20V1-3. pdf [accessed 2017-06-19] [WebCite Cache ID 6rL6WyOZC]

29.   Puyau MR, Adolph AL, Vohra FA, Zakeri I, Butte NF. Prediction of activity energy expenditure using accelerometers in children. Med Sci Sports Exerc 2004 Sep;36(9):1625-1631. [Medline: 15354047]

30.   Hagler AS, Calfas KJ, Norman GJ, Sallis JF, Patrick K. Construct validity of physical activity and sedentary behaviors staging measures for adolescents. Ann Behav Med 2006 Apr;31(2):186-193. [doi: 10.1207/s15324796abm3102_11] [Medline: 16542134]

31.   Schumann A, Nigg CR, Rossi JS, Jordan PJ, Norman GJ, Garber CE, et al. Construct validity of the stages of change of exercise adoption for different intensities of physical activity in four samples of differing age groups. Am J Health Promot 2002;16(5):280-287. [Medline: 12053439]

32.   De Bourdeaudhuij BI, Philippaerts R, Crombez G, Matton L, Wijndaele K, Balduck AL, et al. Stages of change for physical activity in a community sample of adolescents. Health Educ Res 2005 Jun;20(3):357-366. [doi: 10.1093/her/cyg131] [Medline: 15536126]

33.   Klein HJ, Wesson MJ, Hollenbeck JR, Wright PM, DeShon RP. The assessment of goal commitment: a measurement model meta-analysis. Organ Behav Hum Decis Process 2001 May;85(1):32-55. [doi: 10.1006/obhd.2000.2931] [Medline: 11341816]

34.   Marshall SJ, Biddle SJ. The transtheoretical model of behavior change: a meta-analysis of applications to physical activity and exercise. Ann Behav Med 2001;23(4):229-246. [Medline: 11761340]

35.   Marcus BH, Bock BC, Pinto BM. Initiation and maintenance of exercise behavior. In: Gochman DS, editor. Handbook of Health Behavior Research II: Provider Determinants. Boston, MA: Springer US; 1997:335-352.

36.   Woods C, Mutrie N, Scott M. Physical activity intervention: a transtheoretical model-based intervention designed to help sedentary young adults become active. Health Educ Res 2002 Aug;17(4):451-460 [FREE Full text] [Medline: 12197590]

37.   Atkin AJ, Sharp SJ, Harrison F, Brage S, Van Sluijs EM. Seasonal variation in children's physical activity and sedentary time. Med Sci Sports Exerc 2016 Mar;48(3):449-456 [FREE Full text] [doi: 10.1249/MSS.0000000000000786] [Medline: 26429733]

38.   Bélanger M, Gray-Donald K, O'Loughlin J, Paradis G, Hanley J. Influence of weather conditions and season on physical activity in adolescents. Ann Epidemiol 2009 Mar;19(3):180-186. [doi: 10.1016/j.annepidem.2008.12.008] [Medline: 19217000]

39.   Carson V, Spence JC. Seasonal variation in physical activity among children and adolescents: a review. Pediatr Exerc Sci 2010 Feb;22(1):81-92. [Medline: 20332542]

40.   Shih PC, Han K, Poole E, Rosson M, Carroll JM. Use and adoption challenges of Wearable Activity Trackers. : iSchools; 2015 May Presented at: iConference 2015 Proceedings; Mar 24-27 2015; California, USA URL: http://hdl.handle.net/2142/73649

XSL•FO

RenderX

41. Slootmaker SM, Chinapaw MJ, Seidell JC, van Mechelen W, Schuit AJ. Accelerometers and internet for physical activity promotion in youth? Feasibility and effectiveness of a minimal intervention [ISRCTN93896459]. Prev Med 2010 Jul;51(1):31-36. [doi: 10.1016/j.ypmed.2010.03.015] [Medline: 20380847]

42. Adams MA, Johnson WD, Tudor-Locke C. Steps/day translation of the moderate-to-vigorous physical activity guideline for children and adolescents. Int J Behav Nutr Phys Act 2013 Apr 21;10:49 [FREE Full text] [doi: 10.1186/1479-5868-10-49] [Medline: 23601369]

43. Colley RC, Janssen I, Tremblay MS. Daily step target to measure adherence to physical activity guidelines in children. Med Sci Sports Exerc 2012 May;44(5):977-982. [doi: 10.1249/MSS.0b013e31823f23b1] [Medline: 22051570]

44. Tudor-Locke C, Craig CL, Beets MW, Belton S, Cardon GM, Duncan S, et al. How many steps/day are enough? for children and adolescents. Int J Behav Nutr Phys Act 2011 Jul 28;8:78 [FREE Full text] [doi: 10.1186/1479-5868-8-78] [Medline: 21798014]

45. Ho V, Simmons RK, Ridgway CL, van Sluijs EM, Bamber DJ, Goodyer IM, et al. Is wearing a pedometer associated with higher physical activity among adolescents? Prev Med 2013 May;56(5):273-277 [FREE Full text] [doi: 10.1016/j.ypmed.2013.01.015] [Medline: 23384471]

46. Ridgers ND, McNarry MA, Mackintosh KA. Feasibility and effectiveness of using wearable activity trackers in youth: a systematic review. JMIR Mhealth Uhealth 2016 Nov 23;4(4):e129 [FREE Full text] [doi: 10.2196/mhealth.6540] [Medline: 27881359]

Abbreviations

MVPA: moderate to vigorous physical activity
SMART: specific, measurable, attainable, realistic, and timely