



Effects of a DVD-delivered exercise program on patterns of sedentary behavior in older adults: a randomized controlled trial☆☆☆

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ABSTRACT

Introduction. In the present study, we examined the influence of a home-based, DVD-delivered exercise intervention on daily sedentary time and breaks in sedentary time in older adults.

Methods. Between 2010 and 2012, older adults (i.e., aged 65 or older) residing in Illinois ($N = 307$) were randomized into a 6-month home-based, DVD-delivered exercise program (i.e., *FlexToBa*; FTB) or a waitlist control. Participants completed measurements prior to the first week (baseline), following the intervention period (month 6), and after a 6 month no-contact follow-up (month 12). Sedentary behavior was measured objectively using accelerometers for 7 consecutive days at each time point. Differences in daily sedentary time and breaks between groups and across the three time points were examined using mixed-factor analysis of variance (mixed ANOVA) and analysis of covariance (ANCOVA).

Results. Mixed ANOVA models revealed that daily minutes of sedentary time did not differ by group or time. The FTB condition, however, demonstrated a greater number of daily breaks in sedentary time relative to the control condition ($p = .02$). ANCOVA models revealed a non-significant effect favoring FTB at month 6, and a significant difference between groups at month 12 ($p = .02$).

Conclusions. While overall sedentary time did not differ between groups, the DVD-delivered exercise intervention was effective for maintaining a greater number of breaks when compared with the control condition. Given the accumulating evidence emphasizing the importance of breaking up sedentary time, these findings have important implications for the design of future health behavior interventions.

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1. Introduction

Adults in the United States are remarkably inactive: Less than half meet the minimum level of physical activity necessary to maintain health, and as few as 16% of older adults (i.e., 65 years of age or older) (Centers for Disease Control and Prevention (CDC), 2015) meet these recommendations (Centers for Disease Control and Prevention (CDC), 2014). This is particularly troubling given the well-established associations between physical inactivity and morbidity. Those who are insufficiently active are at increased risk for obesity, type 2 diabetes, several types of cancer, osteoporosis, and poor psychological health

(Warburton et al., 2006). The World Health Organization estimates that 3.2 million deaths per year can be attributed to inactivity, as can nearly 700,000 premature deaths (World Health Organization, 2010). These high rates of inactivity are driven in large part by advances in leisure and occupational technologies within the last century (e.g., widespread use of the automobile; the prevalent use of internet and television) that prioritize efficiency while disincentivizing physical effort (Dunstan et al., 2012a).

These same technologies promote high levels of sedentary behavior even among those who meet or exceed recommendations for moderate to vigorous physical activity (MVPA). For example, a highly-active individual with a sedentary occupation might sleep for 8 h and exercise for 90 min in the morning, leaving 14.5 h each day to sit while commuting, working, and watching television or using the computer. Sedentary behaviors are often characterized by their posture (i.e., sitting, reclining) and by low levels of energy expenditure (i.e., ≤ 1.5 METs) (Dunstan et al., 2012a; Owen et al., 2011). Interestingly, emerging evidence suggests that daily sedentary time, and specifically the presence of long and unbroken bouts of sedentary time that typically characterize

Abbreviations: FTB, *FlexToBa*; MVPA, Moderate-to-vigorous physical activity; ANOVA, Analysis of variance; ANCOVA, Analysis of covariance.

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many occupational and leisure pursuits, is associated with morbidity (e.g., type 2 diabetes, cardiovascular disease) and mortality (Dunstan et al., 2012a, b; Healy et al., 2008a, b, 2011; Owen et al., 2010). Numerous observational studies suggest these effects are independent of time spent in MVPA. In a sample of 240,819 adults in the United States, Matthews et al. (2012) noted a graded elevation in risk for all-cause mortality with increased time spent watching television, a common form of sedentary behavior. The researchers further examined the role of MVPA for mitigating the mortality risk associated with sitting time, finding that even among individuals meeting or exceeding recommendations for MVPA, large amounts of television viewing were associated with a 1.5 to 2-fold increase in risk for all-cause mortality. A number of studies have also highlighted the importance of the manner in which sedentary time is accumulated (Healy et al., 2008b; Dunstan et al., 2012b). Healy et al. (2008b) examined the influence of breaks in sedentary time on markers of metabolic risk in a sample of 168 adults. The researchers found short, light intensity breaks to be beneficially associated with a number of metabolic markers (i.e., waist circumference, body mass index, triglycerides, 2-h plasma glucose), and these effects were independent of time spent in MVPA and total sedentary time. Findings such as these highlight the importance of reducing and breaking up sedentary time in addition to traditional approaches that focus on increasing time spent in MVPA. Increasing the amount of time spent in light intensity activities (i.e., 1.5–3.0 METs) is one strategy for accomplishing this goal, as these activities represent the primary determinant of daily energy expenditure (Donahoo et al., 2004) and are most likely to be replaced by sedentary behaviors (Dunstan et al., 2012a).

The recent focus on the importance of sedentary time reduction has led to a rapid growth in interventions targeting sedentary behavior. Early intervention work often focused on reducing time spent watching television. For instance, Otten et al. (2009) targeted television viewing in overweight and obese adults. The researchers restricted those in the intervention condition to 50% of their typical television viewing time, utilizing a device to power off the television once this limit is reached. When compared to a control condition, these individuals significantly decreased television viewing time, and this was met with a significant increase in energy expenditure and decrease in accelerometer-measured sedentary time. More recent work has directly targeted sitting in occupational and home contexts, often employing individualized counseling and/or brief prompts to cue individuals to stand. Healy et al. (2013) implemented a multilevel approach to reduce sitting time in office workers by targeting individual, environmental, and organizational elements of the workplace via individualized counseling, sit-stand work stations, and group workshops, respectively. Those randomly assigned to the intervention condition decreased time spent sitting by more than 2 h per day. Outside of the workplace, other researchers have utilized the recent proliferation of smartphones to provide cues to stand throughout the day. Over the course of a three-week feasibility study, Bond et al. (2014) distributed a smartphone application that delivered prompts to stand following three different durations of sedentary time (i.e., 30, 60, and 120 sedentary minutes). Individuals were assigned to each of the three groups in a counterbalanced order, and decreases in sedentary time were reported across all conditions.

This small body of research demonstrates that sedentary time and breaks in sedentary time are important health behaviors that are amenable to change. Still, many interventions that have targeted sedentary behaviors have been relatively brief in duration and would be difficult to deliver broadly (e.g., those with one-on-one counseling), limiting access for those of greatest need but who are unable to travel to a counseling session, such as older adults or those living in rural areas (Dunstan et al., 2012a; Owen et al., 2011; Clark et al., 2010). Designs that have taken advantage of technology to allow for broader delivery, such as those implementing smartphone-based prompting, may not provide sufficient support for long-term behavior change (Dennison et al., 2013). Finally, although older adults engage in the greatest proportion

of sedentary time (Matthews et al., 2008, 2012), few interventions have directly targeted this population.

Recent reports describing a theory-driven, DVD-delivered, home-based exercise intervention for older adults (i.e., the *FlexToBa* program, hereafter referred to as FTB) (McAuley et al., 2012, 2013; Gothe et al., 2014; Fanning et al., 2015; Wójcicki et al., 2014) have demonstrated that such an approach holds promise for changing health behaviors among older adults. Though the program was designed to improve physical function by targeting elements of flexibility, strength, and balance, it produced improvements in accelerometer-measured MVPA (Gothé et al., 2014), and these effects were maintained across an extended no-contact period (Fanning et al., 2015) (see McAuley et al., 2012; Gothe et al., 2014) for detailed physical function and physical activity outcomes). Indeed, there are a number of features of the FTB program that indicate it may be an effective vehicle for influencing sedentary behaviors in older adults. It was delivered in the home via the television, a device which accounts for the greatest amount of time spent in leisure-time sedentary activity (Bureau of Labor Statistics, 2015). Exercise logs were placed in a visible location as a visual cue for activity in the home. Finally, each participant received a handbook outlining the progression of the program, discussing safe exercise, and providing tips for engaging in additional activity throughout the day, many of which focused on replacing sedentary behaviors with light activities (e.g., stand or ride a stationary cycling while watching television).

Accordingly, the purpose of this study is to examine whether a theory-based, DVD-delivered exercise program yields improvements in sedentary time outcomes in older adults, and whether these improvements are maintained over a six month, no-contact follow-up period. We hypothesized that those who received a DVD-based exercise program would report less daily sedentary time and more daily breaks in sedentary time at month 6. Additionally, given that those in the intervention condition retained the DVD and handbook across a no-contact follow-up period, we further hypothesized that these effects would be maintained at month 12.

2. Methods

2.1. Study design and interventions

The full study procedures, including the CONSORT diagram, are provided elsewhere (McAuley et al., 2012, 2013). Briefly, between 2010 and 2012, low active (i.e., ≤ 2 days per week of physical activity lasting greater than 30 min or more over the last six months), community dwelling older adults ($N = 307$) were recruited from a broad geographic region of central Illinois to participate in FTB, a six-month, DVD-delivered exercise program targeting flexibility, toning, and balance. Eligible participants were randomly assigned to the exercise intervention condition or to a waitlist control. Those in the intervention condition received an introduction DVD containing important information about safe exercise in addition to other healthy living information (e.g., replacing sitting behaviors, eating healthfully). These participants also received six DVD-based exercise sessions. Each session was designed to be used every other day for one month, and each one increased in complexity and difficulty relative to previous sessions. In addition to the DVDs, each participant received a yoga mat and two exercise bands of varying resistance. Exercise binders containing exercise logs and goal-setting worksheets were also provided. Participants completed exercise logs each day and mailed them on a monthly basis to the research staff, and data from these logs were used to provide individualized feedback. Participants were encouraged to place materials in a visible location as a cue to complete logs and engage in the program. Those in the control condition received the commercially available “Healthy Aging DVD” by Dr. Andrew Weil, which covers a variety of age-appropriate health topics. Following the month 12 assessment, control individuals

received the FTB package. All study procedures were approved by a university Institutional Review Board.

2.2. Measures

Sedentary time was assessed objectively using Actigraph brand accelerometers (Actigraph, Pensacola, FL; model GT1m or GT3x). Each participant was instructed to wear the device on the non-dominant hip for one week during waking hours. These data were collected prior to the first week (baseline), following the intervention period (month 6), and after a 6 month no-contact follow-up (month 12). Upon receipt from the participant, these data were processed with an interruption period of 60 min, and those with at least 10 h of wear time on at least three days were retained for analysis (Troiano et al., 2008). The data were then scored such that each 1-min epoch with fewer than 100 counts was considered sedentary time, and the transition from sedentary time to activity of greater than 100 counts was considered a break in sedentary time (Healy et al., 2008a). To account for differences in number of days of accelerometer wear, all variables were then divided by the number of valid days to represent average daily values. All processing and scoring was conducted within Actilife, version 6 (Actigraph, Pensacola, FL).

2.3. Data analyses

Independent samples t-tests were first conducted to determine whether there were any differences between groups in demographics (i.e., gender, age, education, income, race) and sedentary outcomes at baseline. Additional t-tests were conducted to determine whether there were differences between individuals who did and did not have sufficient data across all three measurement time points. Next, a series of mixed-model analyses of variance (i.e., mixed ANOVA) were conducted to examine whether there were any differences in average sedentary time and number of breaks in sedentary time following the structured exercise program and across the follow-up period. In each analysis, average daily values at month 6 and month 12 for sedentary time or breaks in sedentary time were entered as within-subjects variables; treatment group was entered as a between-subjects factor; and age, gender, and baseline values for each outcome variable were included as covariates. Additionally, analyses of covariance (ANCOVAs) were conducted to further examine differences in sedentary behavior outcomes at each time point. Again, baseline values, age, and gender were included as covariates. Results were considered significant at $p < .05$. All analyses were conducted in SPSS version 22 (IBM Corp., Armonk, NY).

3. Results

Of the 307 participants initially randomized, 221 (72%) had sufficient accelerometer data across all time points (see Table 1 for average accelerometer wear across the study period). There were no differences between groups at baseline (all $ps \geq .10$), and those with sufficient data across time points did not differ on demographic factors from those without sufficient data, with the exception of education ($p < .01$). Individuals with valid data across all three time points were more likely to have a college education than were those without complete data. Participant characteristics are summarized in Table 1.

The mixed ANOVA for daily sedentary time indicated there were no significant differences between groups across the follow-up period. The main effects for time and group were not significant [$F(1,216) = .001$, $p = .37$, $\eta^2 = .000$ and $F(1,216) = .908$, $p = .34$, $\eta^2 = .004$, respectively], nor was the group \times time interaction [$F(1,216) = .003$, $p = .96$, $\eta^2 = .000$]. Regarding number of daily breaks in sedentary time, the main effect for time was not significant [$F(1,216) = .023$, $p = .88$, $\eta^2 = .000$], but the main effect of group was significant [$F(1,216) = 5.024$, $p = .02$, $\eta^2 = .023$], indicating that those in the FTB condition

Table 1

Participant and accelerometer characteristics. Note: FTB = *FlexToBa*; M = mean; SD = standard deviation.

Measure	FTB (n = 103)	Control (n = 118)
Age (mean, SD)	70.12 (4.79)	71.16 (4.62)
Sex (n, %)		
Female	76 (73.8)	95 (80.5)
Male	27 (26.2)	23 (19.5)
Race (n, %)		
African American	2 (1)	2 (1.7)
Asian	1 (1)	1 (0.8)
Native American	1 (1.9)	0 (0)
White	98 (95.1)	114 (96.6)
Education (n, %)		
Non-college graduate	47 (45.6)	66 (55.9)
College graduate	56 (54.4)	52 (44.1)
Income (n, %)		
<\$40,000	44 (42.7)	61 (51.7)
≥\$40,000	59 (57.3)	56 (47.5)
Accelerometer wear time (M days, SD)		
Month 0	6.76 (.63)	6.73 (.82)
Month 6	6.79 (.96)	6.35 (1.07)
Month 12	6.50 (1.06)	6.62 (1.07)

had a greater number of breaks across the follow-up period relative to the control condition. The group \times time effect was also non-significant, [$F(1,216) = 1.041$, $p = .31$, $\eta^2 = .023$]; however, a trend was apparent indicating those who received the intervention maintained a higher number of sedentary breaks across the no-contact period, while a significant decrease was observed in control individuals. The ANCOVA revealed a non-significant group effect favoring the intervention condition at month 6 [$F(1,241) = 2.21$, $p = .14$, $\eta^2 = .009$], and a significant difference between groups at month 12 [$F(1,220) = 5.645$, $p = .02$, $\eta^2 = .025$]. Specifically, those in the FTB condition engaged in four more breaks per day, on average (see Tables 2 and 3).

4. Discussion

Although modest, these results partially support our hypotheses, suggesting a DVD-delivered exercise program may protect against long, unbroken bouts of sedentary time in older adults. These results are of particular importance in light of the recent body of evidence suggesting that long, unbroken bouts of sedentary behavior are effective predictors of morbidity, perhaps to a greater degree than total sedentary time (World Health Organization, 2010). Further, previous research has called for the examination of the influence of various physical activity intervention types on sedentary outcomes (Owen et al., 2011), and to the best of our knowledge this is the first to do so with a broadly delivered home-based exercise program for older adults.

Given the focus of the FTB program on improving physical function via exercise, the effect on sedentary breaks is promising, perhaps highlighting some of the advantages of the method of delivery. Moreover, it is not surprising that the magnitude of this effect was rather small. Relative to physical activity engagement, sedentary behavior has unique psychosocial and environmental determinants, and some have suggested that it has a strong automatic and non-conscious

Table 2

Unadjusted sedentary outcomes. Note: FTB = *FlexToBa*.

	FTB mean (SD)	Control mean (SD)
Daily sedentary time (minutes)		
Month 0	596.54 (96.40)	586.21 (82.85)
Month 6	593.49 (72.71)	581.62 (76.07)
Month 12	598.36 (84.54)	585.66 (73.52)
Daily sedentary breaks (n)		
Month 0	78.31 (16.11)	80.10 (15.95)
Month 6	79.48 (15.12)	78.61 (15.51)
Month 12	77.99 (16.43)	75.42 (17.07)

Table 3
Sedentary behavior outcomes, adjusted for baseline values, age, and gender.

	FTB mean (SE)	Control mean (SE)	p
Daily Sedentary Time (minutes)			
Month 6	590.48 (5.78)	584.24 (5.40)	.47
Month 12	595.16 (6.01)	588.24 (5.61)	.48
p [†]	.43	.42	
Daily Breaks in Sedentary Time (n)			
Month 6	80.143 (1.125)	78.034 (1.051)	.17
Month 12	78.682 (1.179)	74.819 (1.101)	.02*
p [†]	.24	.01*	

Note: FTB = *FlexToBa*.

[†] p-Value for within-group change from month 6 to month 12.

* p < .05.

element (Owen et al., 2011; Conroy et al., 2013). Sitting is facilitated by the physical and social environment (e.g., park benches, office chairs, seated meetings), and is often required in large doses (e.g., seated office work, daily commutes). Additionally, evidence suggests that a number of socioeconomic factors influence an individual's time spent sitting (Owen et al., 2010; Matthews et al., 2012; Sugiyama et al., 2007).

In light of these factors, recent recommendations suggest sedentary behavior be targeted at multiple levels of influence (Owen et al., 2011; Manini et al., 2014). Owen et al. (2011) posited an ecological model of sedentary behavior describing the multiple levels of influence on sedentary behavior (i.e., intrapersonal, perceived environmental, behavioral domains, behavioral setting, and policy factors), which interact with one another such that change at one level may produce change within others (see Fig. 1). In this model, it is hypothesized that targeting multiple levels of influence will yield more robust behavior change relative to interventions targeting individual-level factors alone (Sallis et al., 2008). Fortunately, interventions designed in social cognitive theory

(SCT) (Bandura, 1986, 1997) may integrate well with ecological approaches to changing health behavior, as SCT targets both personal and immediate environmental factors related to a behavior (Satariano and McAuley, 2003; King et al., 2002). For example, FTB directly targets self-efficacy; a key intrapersonal psychological construct within SCT that is consistently identified as a leading determinant of health behavior (Bandura, 1997, 2004; McAuley and Blissmer, 2000). Efficacy beliefs may directly influence one's perceptions of his or her environment by altering perceived barriers and impediments to the behavior (Bandura, 2004). Within behavioral domains (i.e., leisure time, household, transport, occupational activity), altering perceived social norms or providing effective models for a behavior may again influence efficacy and behavior. Importantly, social cognitive interventions aiming to improve sedentary behavior have demonstrated success. For example, Gardiner et al. (2011) implemented a single-session counseling program aimed at improving sedentary behavior outcomes in older adults. The researchers specifically focused on improving self-efficacy via goal setting and outcome expectancies, and were successful in reducing sedentary time and increasing number of breaks in sedentary time.

Simple sitting time reduction strategies, such as those used by Gardiner et al. (2011) can be readily introduced to FTB's introduction and exercise videos. The resulting video-based package provides a number of promising features on which researchers might build an effective multilevel intervention. For instance, individuals are asked to view a given session 12 or more times before moving to the next video, and they retain access to each video at the end of the program. Accordingly, participants are repeatedly exposed to expert-crafted cues and strategies, and may continue to receive these messages following the completion of the program. Age-appropriate models might demonstrate sitting time reduction techniques in order to improve self-efficacy via vicarious

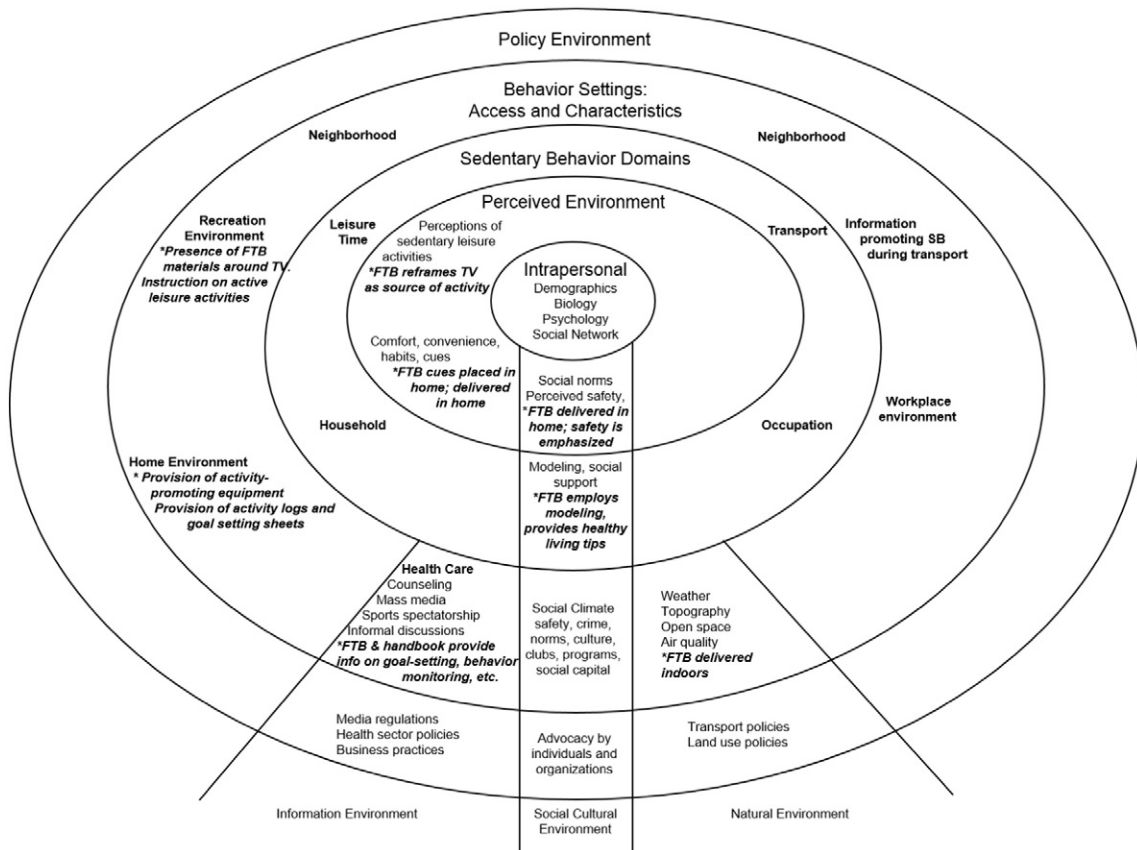


Fig. 1. Adapted ecological model of sedentary behavior (Owen et al., 2011, used with permission of the author) and the proposed impact of the FTB program on levels of influence on sedentary behavior. Note: FTB = *FlexToBa*; TV = television; SB = sedentary behavior.

experience. Goal-setting instructions and worksheets may target both physical activity and sedentary time goals, and individualized program feedback can be expanded to include progress on both types of goals. In addition to addressing these intraindividual and perceived environmental levels of influence, the FTB program alters the behavioral setting in which the majority of leisure-time sedentary activity occurs: the home environment. More specifically, the television adopts a new role as a medium for physical activity intervention delivery. Additionally, the presence of program materials near the television and around the home provides cues to engage in activity and to avoid sitting time. These changes to the context in which the behavior occurs are important for supporting positive physical activity and sedentary behavior change in the long term (Owen et al., 2011).

Perhaps most importantly, the FTB program is able to provide these resources from afar, without the need for face-to-face interaction between research staff and participants. This allows researchers and practitioners to focus on policy and environmental change. As recommendations accumulate indicating the need for multilevel interventions addressing sitting behavior, future researchers may consider the delivery of the FTB program alongside sitting-time reduction strategies within a community or workplace intervention targeting the local environment and policy.

4.1. Limitations

Despite its novelty, there are several limitations present in the current study. First, individuals who were retained across all time points tended to have a higher education than those who were not. Given that education level is negatively associated with sedentary time (Owen et al., 2010; Clark et al., 2010), this may have mitigated a portion of the effect. The sample was also largely female (~77%) and white (~96%), limiting the generalizability of the findings. Future research extending these findings into more diverse samples is warranted. Finally, it is difficult to determine the clinical significance of four daily breaks in sedentary time. The collection of biomarkers often associated with sedentary time may help to clarify whether these modest changes in breaks produce meaningful effects on health. Moreover, as increasing focus is placed upon the impact of sitting behaviors on health, a debate regarding whether these behaviors are independently related to morbidity and mortality has grown (Pulsford et al., 2015). The collection of health markers, as well as objective indicators of sedentary time, may further illuminate these relationships. Despite these limitations, we believe that this study offers important insight for the rapidly expanding body of evidence on intervening upon both physical activity and sedentary time.

5. Conclusion

The FTB program was successful in promoting breaks in sedentary time, a promising finding given the program did not address sedentary behavior directly. The progressive, home-based, and video-delivered platform is promising for large-scale delivery while targeting multiple levels of influence on MVPA and sedentary behaviors alike. Future research implementing these techniques via contemporary technologies (e.g., streaming video) that allow for still broader dissemination may produce a significant public health impact.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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