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Effectiveness and feasibility of family and peer challenge intervention with wearable technology on physical activity among middle schoolers in Utah: A pilot trial☆

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ABSTRACT

Objective: To examine the preliminary effectiveness and feasibility of physical activity (PA) intervention in middle schoolers.
Methods: This 6-week, multi-component PA intervention was conducted in Salt Lake City, Utah, between November 2021 and January 2022. The intervention included tracking daily PA using a wearable activity monitor, education on PA and health, weekly motivational videos, and group challenges within family or peer groups. Three classes from one public middle school ($N = 75$; 51 % girls, aged 12–13 years) were randomly allocated into the intervention (i.e., family or peer challenges) or control groups. Changes in daily activity time between pre- and post-intervention were assessed using ActiGraph accelerometers. The feasibility of the intervention was evaluated through measures of adherence, retention, and acceptability.
Results: After the intervention, 51 (girls: 51 %; age: 13.0 ± 0.7) of all participants completed the entire study protocol. Linear mixed models showed no statistically significant differences between interventions and control in daily sedentary behavior and PA times. Adherence to the intervention was moderately high (> 60 %), with a retention of 68 %. We also observed high satisfaction with wearable technology (≥ 78 %) in middle school students. However, only 39 % of participants frequently used the mobile app for their group challenge.
Conclusions: Wearable technology in PA intervention may be of interest to young adolescents but not effectively change youth PA behavior during a 6-week intervention. Further research with larger samples, longer intervention durations, and refined engagement strategies is required to more accurately evaluate the impact and feasibility of this intervention.

1. Introduction

Adolescence is a critical development period for establishing a physically active lifestyle correlated to lifelong health benefits. Regular physical activity (PA) in adolescents improves bone mineral density, muscular strength, cardiovascular function, and mental health and reduces the prevalence of obesity (Janssen and Leblanc, 2010; Mark and Janssen, 2011). Accordingly, the Centers for Disease Control and Prevention recommends that children and adolescents should engage in at least 60 min of moderate- to vigorous-intensity PA (MVPA) daily (*Physical Activity Guidelines for Americans*, 2018). Despite this, only 19 % of boys and girls aged 11–17 meet the daily PA recommendation (*Global status report on physical activity* 2022 (World Health Organization), 2022). Given that PA habits at an early age appear to influence PA levels in adulthood (Telama et al., 2005), promoting regular PA at school age is an important target in public health. Thus, it is imperative to develop sustainable and effective interventions aimed at increasing PA levels among middle schoolers.

A promising approach for PA promotion is the integration of behavior change techniques (BCTs), which are evidence-based strategies

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aimed at improving health-related behaviors (Hynynen et al., 2016; Michie et al., 2011). According to Social Cognitive Theory, self-monitoring, goal-setting, feedback, and social support have been identified as effective BCTs that can enhance PA engagement in youth (Hynynen et al., 2016; Michie et al., 2013). For example, self-monitoring—where individuals track and observe their own behavior—has been shown to increase MVPA time in elementary school students significantly (McLoughlin et al., 2019). Additionally, social interactions that provide parental and peer support have been linked to higher PA participation in adolescents (Beets et al., 2006). This evidence suggests that a successful PA intervention should integrate behavioral skill development with social support, such as family and peer involvement.

One emerging strategy for delivering BCT-based interventions is wearable activity monitors (WAMs) (Thompson, 2019; *Statistica. Wearables - statistics and facts,* 2022). WAMs, when combined with a mobile app, provide real-time feedback and goal-setting features that align with effective BCTs for PA promotion. (Michie et al., 2013; Lyons et al., 2014) Multi-component interventions incorporating WAMs have shown promise in increasing PA participation (Brickwood et al., 2019), often leveraging additional strategies like goal setting (Gaudet et al., 2017; Hooke et al., 2016), incentives (Evans et al., 2017), or online education (Chen et al., 2017). Given that multi-component PA interventions tend to be more effective than single-component approaches (Hynynen et al., 2016), integrating WAMs within structured intervention programs may provide a cost-effective and engaging way to promote PA in adolescents (Lyons et al., 2014).

Despite the potential of WAMs to enhance PA engagement (Ridgers et al., 2016), the evidence regarding their effectiveness in young adolescents remains limited and mixed (Creaser et al., 2021). Some studies have demonstrated positive effects, such as increased step counts and MVPA time (Larson et al., 2018; Buchele Harris and Chen, 2018), while others have reported no significant improvements or even negative impacts on PA behavior (Evans et al., 2017; Ridgers et al., 2021; Heale et al., 2018). One potential limitation of previous research is the lack of integration between wearable-based interventions and key social support, such as family and peer support, which play a crucial role in shaping PA behaviors in adolescents (Dunton et al., 2007; Gill et al., 2018).

To address this gap, this pilot study aimed to evaluate the preliminary effectiveness of a wearable technology-based PA intervention incorporating family and peer challenges on daily PA levels among middle schoolers. The intervention was designed based on key behavioral change techniques (self-monitoring, goal-setting, and feedback) and social support (family and peer interactions) to enhance PA engagement. Given the importance of understanding how to optimize wearable technology-based interventions for youth, the findings from this study may help inform future large-scale PA promotion strategies tailored for adolescents.

2. Methods

2.1. Study design

The evaluation of the intervention was conducted through a three-arm group randomized controlled trial in which questionnaires and accelerometry measures were used. The Consolidated Standards of Reporting Trials (CONSORT) statement was used to report the cluster of randomized controlled trials in this study (Campbell et al., 2012).

2.2. Participants

One public middle school in Salt Lake City, Utah was invited and agreed to participate through email and local advertisements circulated to teachers. The study was conducted between November 2021 and January 2022. Three classes within the middle school were randomly selected and then randomly allocated into one of the three groups: (a) the peer challenge group (PCG), (b) the family challenge group (FCG), or (c) the control group. Students who were 13 or younger, could participate in PA on their own, and spoke and read English were eligible for the study. Students who are physically disabled or unable to perform PA as recommended by physicians were excluded from the study. A total of 79 young adolescents were recruited. We obtained informed consent from children and their parents. The study was performed in accordance with the ethical standards of the University of Utah Institutional Review Board.

2.3. Intervention

This study implemented a six-week, multi-component PA intervention designed to improve middle schoolers' PA levels. The intervention was developed based on Social Cognitive Theory (SCT), which emphasizes the interaction of personal, environmental, and behavioral factors in influencing health behavior (Salmon et al., 2007). The SCT-based constructs included self-efficacy, behavior skills, social support, and social influence, which were integrated into the intervention components. Supplement Table 1 summarizes the intervention approach.

Both the control and intervention groups received three common components to improve self-efficacy and behavioral skills development as follows:

1. *Self-monitoring for daily PA levels and PA goal setting* via *a wrist-worn WAM and mobile app.* Fitbit activity monitors and mobile apps incorporate BCTs, such as self-monitoring, goal setting, and social support (Düking et al., 2020). Self-monitoring of PA levels and setting personalized PA goals reinforces self-efficacy by enabling them to track progress over time.
2. *Education on PA and health benefits* via *a 7*-min *presentation before the intervention.* The educational presentation highlighted the risks of inactivity, health benefits from regular PA, recommended MVPA levels for adolescents, and suitable activities like cycling and running. The presentation also described the overall study protocol that was followed in a classroom setting.
3. *Weekly motivational videos.* Participants received web links to motivational videos via text message throughout the six-week intervention. Participants were requested to watch motivational videos to learn about the appropriate protocol for developing fitness, daily fitness logs for self-monitoring, goal-setting strategy, energy balance, the way of daily PA, and the health benefits of PA. These web-based resources promote behavior change and confidence to maintain healthy behavior (Michie et al., 2013).

Intervention groups. Fitbit group challenge (i.e., family or peer challenge) was another intervention component for intervention groups. Participants in the PCG joined a Fitbit App challenge with classmates, sharing their PA levels via a leaderboard. This strategy encouraged social influence, allowing participants to be motivated by their peers' activity levels. Participants in the FCG joined a challenge with a parent, sharing progress like daily steps and MVPA time. Parents received educational summaries electronically to encourage family discussions about PA. Trained research staff joined in PCG or FCG, providing feedback and encouragement based on PA tracking and coordinating group interaction.

2.4. Wearable activity monitor

The Fitbit Inspire 2, a wrist-worn activity monitor, was used to promote participants' PA engagement. Fitbit devices and mobile apps can incorporate 17 BCTs, including goal setting, feedback on PA progress, self-monitoring of PA, and social support (Düking et al., 2020). The Fitbit Inspire 2 tracks steps, activity time, energy expenditure, and heart rate, and features a real-time OLED display with personalized daily PA goal setting. Additional features include hourly movement reminders and feedback via vibrations and visual cues, helping adolescents understand and monitor their PA levels. The Fitbit mobile app offers a family account and group challenge feature, enabling social connection. In this study, participants shared PA progress and received group motivation through the app. For example, parents in the FCG could view their child's daily PA patterns and provide support via the shared dashboard.

2.5. Procedure

Baseline assessments included demographic and anthropometric characteristics (i.e., age, gender, height, and weight) via questionnaires and daily PA levels using ActiGraph wGT3X-BT accelerometers (wGT3X-BT; ActiGraph, Pensacola, FL, USA) worn for seven consecutive days during all waking hours. The participants' BMI was calculated by dividing weight (in kilograms) by height squared (in square meters). Following the baseline assessment, research staff visited the school to deliver a seven-minute educational presentation on PA benefits, risks of inactivity, and adolescent PA guidelines and distribute Fitbit devices to study participants. Research staff assisted participants with setting up their Fitbit accounts and devices, including how to charge the devices and sync them to the Fitbit mobile app. Participants were required to wear their Fitbit and frequently monitor their activity accumulation throughout the six-week intervention.

During the intervention period, all participants received weekly educational videos via text and the Fitbit app, promoting twice-daily PA tracking. Research staff supported the PCG with goal setting, motivational video reminders, and leaderboard checks. Briefly, on Mondays, participants set weekly goals after watching motivational videos; on Thursdays or Fridays, the PCG reviewed their activity progress and leaderboard in the group. The FCG communicated with their parents to achieve family or individual PA goals using the Fitbit family challenge. The control group used Fitbit only for self-monitoring. Immediately after the six-week intervention, all participants wore the wGT3X-BT for seven consecutive days and completed a feasibility survey. Fitbit Inspire 2 devices were given as participation compensation.

To ensure consistent intervention delivery, participants received standardized instructions on device setup and group challenge procedures. Research staff routinely engaged with participants to provide assistance and resolve concerns. All staff underwent structured training covering the study protocol, research ethics, communication, Fitbit setup, app synchronization, and troubleshooting. Additionally, research staff rehearsed educational presentations with standardized scripts.

2.6. Outcome measures

2.6.1. Sedentary behavior and physical activity

Participants' PA levels were assessed for seven consecutive days using a hip-worn wGT3X-BT at pre- and post-intervention. The wGT3X-BT has been widely used to assess individuals' time engaged in sedentary behavior (SED), light PA (LPA), and MVPA in a free-living condition (Ridgers et al., 2021; Duck et al., 2021; Tucker et al., 2011). Participants were instructed to wear the wGT3X-BT on their dominant hip using a belt strap. Raw acceleration data were sampled at 30 Hz and converted to activity counts per 15 s using ActiLife 6 software for further analysis. The activity count data were processed using Evenson cut-points to categorize minutes spent in SED ($<$ 101 CPM), LPA (101 to $>$2295 CPM), and MVPA ($\geq$ 2296 CPM) during waking hours (Evenson et al., 2008). These values are recommended as the most suitable cut points for children and adolescents (Migueles et al., 2017). Also, non-wear times were defined using Choi's algorithm (Choi et al., 2011) and excluded from the final data set. The processed data was aggregated to the daily average for statistical analysis. Also, the current study included data at baseline and immediate post-intervention for statistical analyses if the wGT3X-BT had been worn for at least three days (Wang et al., 2015).

2.6.2. Intervention feasibility

The feasibility of the wearable technology-based PA intervention was evaluated using the following criteria: (1) recruitment of 75 participants, (2) a retention rate of 60 %, (3) 60 % adherence, (4) no serious adverse events, and (5) achieving high satisfaction (acceptability) rates with Fitbit device, mobile apps, and group challenge features. The acceptability criterion was set following published feasibility trial guidelines, where an intervention is considered acceptable if a substantial majority of participants report satisfaction. Intervention completion rates and PA assessment measured retention via accelerometers. Adherence and acceptability were assessed through responses about Fitbit device, mobile app, and group challenge usage and satisfaction on a 5-point Likert scale. The percentage of PCG and FCG participants who responded 'often' or 'almost often' to the three questions regarding their use of the Fitbit device and mobile app and the checking challenge group were calculated to evaluate adherence. The acceptability was determined if at least 75 % of participants reported 'Satisfied' or 'Very Satisfied' on a 5-point Likert scale. The recruitment target of 75 participants was set based on previous school-based interventions' participation rates (Creaser et al., 2021). Based on previous feasibility trials in youth populations (Lyons et al., 2014), retention and adherence thresholds ($\geq$ 60 %) were set to consider sustainability and scalability for future larger trials (Bowen et al., 2009).

2.7. Statistical analysis

Descriptive analyses were conducted for all measured variables, including anthropometric characteristics and device-based assessed PA levels. Linear mixed models were used to estimate the between-group and within-group differences for accelerometry outcomes. The models included fixed effects for group, time, and group-by-time interaction. A participant-level random intercept was included in the models to adjust for a nested data structure (i.e., repeated measurements within participants). The initial model was adjusted for accelerometer wear time. Additionally, the final model was adjusted for age, sex, and BMI percentile. Effect sizes for the changes of daily SED and PA were calculated using Cohen's d to describe the magnitude of any potential intervention effects. An alpha level of 0.05 was set to define the significance of statistical analyses. All statistical analyses were conducted using Stata SE 17 software (StataCorp LLC, College Station, TX, USA).

3. Results

3.1. Descriptive characteristics and retention

A total of 79 students were recruited for the study, with 4 withdrawing before baseline measurements. At baseline, 75 students (age: 12.9; girls: 51 %) completed the seven-day PA assessment using a hip-worn accelerometer and were allocated to control and intervention groups. The participants had an average BMI of 24.1 kg/m^2 ($\pm$ 6.6), indicating predominantly healthy body weights. The study flow diagram is detailed in Fig. 1.

Retention in the 6-week intervention was moderately high (51/75, 68 %). Of the 75 participants, 13 dropped out during the intervention, and 11 were lost to follow-up due to insufficient accelerometer wear time ($<$600 min/day), primarily in the PCG (5 of 11). The FCG had the lowest retention rate (64 %), with eight dropouts in each group. Ultimately, 51 participants (age: 13.0; girls: 51 %) provided valid accelerometry data for final analysis. No serious adverse events were reported. The descriptive characteristics of the participants for the baseline and completers are presented in Table 1.

3.2. Sedentary behavior and physical activity

Post-intervention, accelerometer wear time increased by 13.4 min/day but was not statistically significant. At post-intervention,

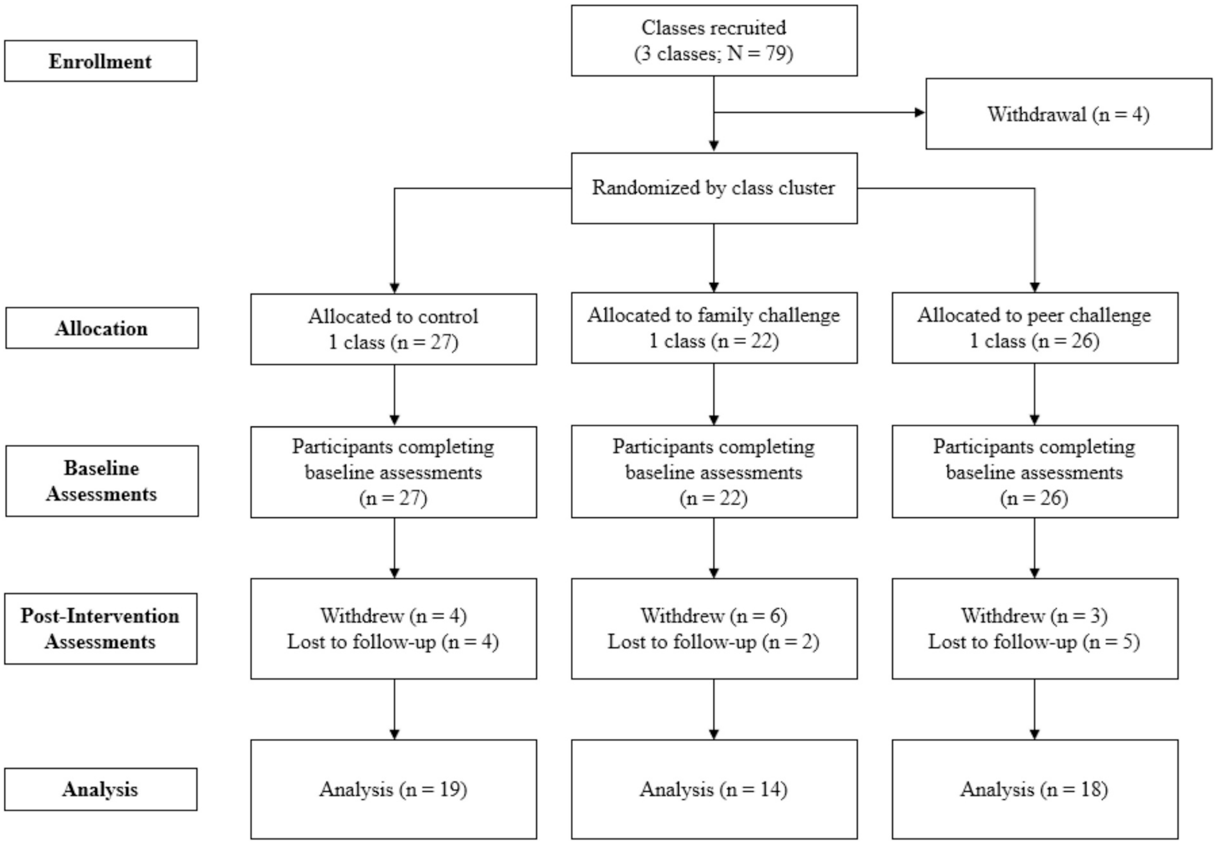

Fig. 1. CONSORT flow diagram of a six-week wearable-based intervention study with middle schoolers in Utah, 2021–2022.

Table 1
Descriptive demographic and anthropometric characteristics of Utah middle schoolers who participated in a six-week wearable-based physical activity intervention between November 2021 and January 2022.

Characteristic	Overall		Control		Family challenge		Peer challenge	
	Baseline	Completers	Baseline	Completers	Baseline	Completers	Baseline	Completers
N	75	51	27	19	22	14	24	18
Age (years)	12.9 ± 0.6	13.0 ± 0.7	12.3 ± 0.5	12.4 ± 0.5	13.3 ± 0.5	13.5 ± 0.5	13.2 ± 0.4	13.2 ± 0.4
Girls, *n* (%)	38 (51.0 %)	26 (51.0 %)	12 (44.4 %)	8 (42.1 %)	12 (54.5 %)	7 (50 %)	14 (58.3 %)	11 (61.1 %)
BMI (kg/m^2)	24.1 ± 6.6	20.4 ± 5.1	20.8 ± 8.2	19.3 ± 3.5	21.8 ± 5.1	21.4 ± 4.6	20.9 ± 5.8	20.7 ± 6.5
BMI percentile (%)	59.2 ± 32.9	57.1 ± 32.4	58.7 ± 36.2	57.9 ± 35.9	60.7 ± 31.5	59.4 ± 30.3	58.5 ± 31.9	54.3 ± 31.0

N: Number of participants; BMI: Body mass index.
Note: Values are presented as mean ± standard deviation for Age, BMI, and BMI percentile.

participants in the FCG and PCG spent 18.7 and 4.2 min less SED time per day than those in the control group, respectively; however, these differences were not statistically significant (FCG: 95 % CI = − 54.6 to 17.2, $p = 0.31$; PCG: 95 % CI = − 38.1 to 29.7, $p = 0.81$). Also, the FCG and PCG engaged in 7.5 and 4.3 min more LPA per day, respectively, compared to the controls following the intervention period; however, the intervention effect on daily LPA time was not statistically significant. There were no statistically significant differences in daily MVPA time between the intervention groups and the control group post-intervention. Despite this, the FCG engaged in 11.0 min more MVPA per day than controls, with a large effect size ($d = 0.80$). The results of the linear mixed models for between-group comparisons in SED and PA are presented in Table 2.

3.3. Adherence to the intervention

The adherence results for the intervention are displayed in Fig. 2-A. Fitbit device usage was moderately high (60 % often or almost always), with the controls (63 %) and FCG (61 %) showing similar adherence, while the PCG was lower (56 %). Mobile app usage adherence was generally low (38 %), with only 33 % reporting frequent exercise induction via the app (FCG: 22 %, PCG: 44 %). Moreover, few participants frequently checked the mobile app for their group challenge (39 % often or almost always), with the PCG showing higher adherence (56 %) than the FCG (22 %).

3.4. Acceptability

Most participants were satisfied or very satisfied with the Fitbit activity monitor (74 %) and mobile app (81 %), with intervention group satisfaction reaching over 80 % for tracking daily PA. Satisfaction was slightly higher in the PCG (Fitbit: 83 %, Mobile app: 89 %) compared to the FCG (Fitbit and Mobile app: 78 %). However, only 42 % of intervention participants were satisfied or very satisfied with the group challenge feature, with higher acceptability in the PCG (50 %) than in the FCG (33 %), as shown in Fig. 2-B.

Table 2
Comparison of changes in daily time spent in sedentary behavior, light physical activity, and moderate-to-vigorous physical activity between groups in a 6-week wearable-based intervention with Utah middle schoolers between November 2021 and January 2022.

	b (SE)	95 % CI	Cohen's *d*
Sedentary behavior, minutes per day			
Family challenge	− 18.7 (18.3)	− 54.6, 17.2	0.02
Peer challenge	− 4.2 (17.3)	− 38.1, 29.7	0.20
Light physical activity, minutes per day			
Family challenge	7.5 (15.7)	− 23.4, 38.4	0.26
Peer challenge	4.3 (14.9)	− 24.8, 33.4	0.04
Moderate-to-vigorous physical activity, minutes per day			
Family challenge	11.0 (7.5)	− 3.8, 25.8	0.80
Peer challenge	− 0.1 (7.1)	− 14.1, 13.9	0.03

b: Coefficient; SE: Standard error; CI: Confidence interval
Effect size (Cohen's *d*): very small = 0.00–0.19, small = 0.20–0.49, medium = 0.50–0.79, and large = 0.80.
Note: This final model was adjusted for accelerometer wear time, age, sex, and BMI percentile.

4. Discussion

The study evaluated the preliminary effects and feasibility of the FCG and PCG interventions using wearable technology on adolescents' daily SED and PA time. While using the WAM in the intervention was feasible and acceptable among middle schoolers, the 6-week intervention showed no statistically significant impact on daily PA levels, whether used with social support or as a standalone tool. Our findings may provide preliminary information on the crucial components of future wearable technology-based interventions to increase youth PA.

The lack of significant changes in daily PA is partially congruent with previous studies with the youth population using WAMs as an intervention component (Evans et al., 2017; Ridgers et al., 2021). While WAMs can facilitate self-monitoring and feedback for daily PA—key components for behavior change (Michie et al., 2008)—WAM itself may not sufficiently influence PA determinants in a short period (Gaudet et al., 2017; Schaefer et al., 2016). For example, a 12-week wearable-based intervention showed no significant change in self-efficacy and PA enjoyment, both critical for PA determinants (Verswijveren et al., 2022). Additionally, some adolescents might lose interest in WAM use to self-monitor daily PA over time (Slootmaker et al., 2010). As such, future studies should focus on enhancing PA determinants, encouraging long-term use of wearables, and addressing barriers to sustained use to maximize the effectiveness of wearables in youth PA interventions (Creaser et al., 2021).

The lack of significant findings may be attributed to several factors. First, the intervention was conducted during the COVID-19 pandemic's social distancing period and winter break (specifically between November 2021 and January 2022); thus, it is possible that such seasonal and contextual factors could exert an influence on PA engagement among middle schoolers. Second, the intervention components of this study might not be enough to promote social interaction among middle schoolers in the PCG. Although we encouraged the peer challenge participants to interact with each other via mobile app frequently, this virtual interaction may not effectively facilitate the exchange of encouragement, feedback, and companionship among participants as much as physical connection (Golaszewski and Bartholomew, 2019). Lastly, the competitive nature of Fitbit's activity leaderboards may have discouraged some participants, particularly those with lower rankings (Dunton et al., 2007). Middle schoolers' motivation can be boosted by using emotional expression with simple “like” or emoticon capabilities inside mobile apps to praise their peers' goal achievement (Lyons and Swartz, 2017).

Although no statistically significant differences were found, the FCG intervention showed a large effect size on adolescents' daily MVPA, highlighting the potential importance of parental support. Given the small sample, this result should be interpreted as preliminary evidence. Parental support has been recognized as an important factor in promoting PA, particularly through emotional and informational support (e.g., encouragement, role modeling, and discussing PA behavior) (Yao and Rhodes, 2015). Middle schoolers may be influenced by their parents' PA-related beliefs and behaviors, as they spend a considerable amount of time in the family environment (Brustad, 1996). Adolescents in middle school often perceive emotional support from parents when their parents frequently watch and interact with them in engaging PA (Duncan et al., 2005). Additionally, parental PA levels have been positively associated with children's PA levels (Fuemmeler et al., 2011). In terms of informational support, wearable technologies can enhance informational support by making children's PA levels visible to parents, potentially fostering more PA-related discussions at home (Creaser et al., 2021). These findings suggest parental involvement could strengthen wearable-based PA interventions. However, future studies with larger samples and follow-up assessments are needed to confirm these effects.

It is noteworthy that adherence to the Fitbit mobile app usage was low in both the FCG and PCG, reflecting limited engagement with the group challenge feature. Few participants expressed high satisfaction with this function, likely because the app's design targets the general population rather than adolescents. As a result, the group challenge may have lacked appeal for middle schoolers in facilitating their engagement. Thus, it may be necessary to employ age-specific mobile apps or

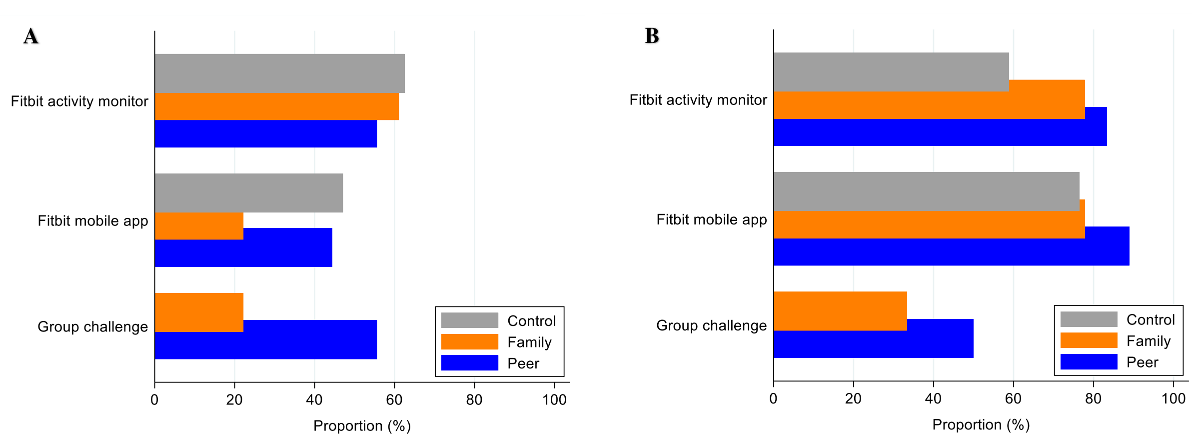

Fig. 2. Participant adherence to and acceptability of the six-week wearable-based physical activity intervention with Utah middle schoolers from November 2021 to January 2022: (A) Adherence: frequency of Fitbit device and mobile app use; (B) Acceptability: participants' satisfaction with Fitbit device, mobile app, and group challenge features.

include additional challenges (Koorts et al., 2020). Potential strategies may include enforcing regular feedback and education on daily PA by teachers or parents, utilizing automatic reminders to promote mobile app use, and fostering partnerships with peers or family.

A strength of this study is that a class unit was randomly assigned to each group, preventing the threat of contamination from individual randomization (Fayers et al., 2002). Another strength is the device-based assessment of youth PA using the widely accepted research-grade accelerometer for seven consecutive days, which provided a more precise and reliable assessment of PA levels (Brooke et al., 2016; Wong et al., 2015). We also used the most widely used consumer-based activity monitor and mobile app to smoothly integrate the multi-component intervention, which is supported by our findings on the intervention feasibility and acceptability.

This study has several limitations. First, due to COVID-19-related school policies, only a small sample from a single middle school was recruited in this pilot study, limiting generalizability and statistical power. Second, the six-week intervention may have been too brief to observe meaningful changes in youth PA behavior. Lastly, while some participants had prior WAM experience, we did not systematically assess or quantify it. This gap limits our ability to evaluate how familiarity with WAMs may have influenced self-monitoring, feedback interpretation, or responsiveness to the intervention. Future studies should systematically assess prior WAM exposure to better understand its influence on outcomes.

5. Conclusion

Our findings showed family and peer challenge interventions with wearable technology did not significantly increase middle schoolers' daily PA time. However, the observed large effect size on the family challenge implies that active family involvement may be an effective component of the PA interventions with wearable technology to increase daily MVPA levels in middle schoolers. We also observed low satisfaction with the Fitbit app's group challenge feature. Due to the limitations above, the findings should be interpreted cautiously. Thus, future research should explore more in-depth how the family and peer challenge via wearable technology enhances middle schoolers' daily PA with a larger sample size, long-term intervention period, and follow-up. Future investigations need to thoroughly assess middle schoolers' PA motivation and involvement to improve group challenge interventions. Lastly, employing mobile apps tailored to youth and enforcing companionship would improve overall acceptance and compliance with this intervention.

CRediT authorship contribution statement

Sunku Kwon: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yang Bai:** Writing – review & editing, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Youngwon Kim:** Writing – review & editing, Methodology. **Ryan D. Burns:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Timothy A. Brusseau:** Writing – review & editing, Supervision, Resources. **Wonwoo Byun:** Writing – review & editing, Supervision, Resources, Methodology, Formal analysis, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no recognized competing financial interests or personal relationships that may have influenced the work presented in this study.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2025.103095.

Data availability

The data that has been used is confidential.

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