International Journal of Physical Activity and Health

Volume 2
Issue 2 *Special Issue: A Synthesis of Recent Studies in Children Activity Intervention*

Article 6

5-1-2023

A Review of Health Wearable-Based Physical Activity Interventions Among Children and Adolescents

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Recommended Citation
Ryu, Suryeon; Rodriguez-Gonzalez, Pablo; and Gao, Zan (2023) "A Review of Health Wearable-Based Physical Activity Interventions Among Children and Adolescents," *International Journal of Physical Activity and Health*: Vol. 2: Iss. 2, Article 6.
DOI: https://doi.org/10.18122/ijpah.020206.boisestate
Available at: https://scholarworks.boisestate.edu/ijpah/vol2/iss2/6

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Abstract

Health wearable technologies have become popular in recent decades to improve individual physical activity (PA) behavior. Thus, this paper aims to examine the health of wearable-based PA intervention among children and adolescents and provide narrative overviews. This paper retrieved articles based on the following inclusion criteria: (1) experimental design; (2) studies among healthy children and adolescents aged from 5 to 18 years; (3) studies using health wearables as a medium to enhance PA or reduce sedentary behavior; and (4) studies with PA assessments as an outcome. Relevant articles were searched based on recent preceding review papers published in 2021 and 2022. A total of 45 studies were included in this review. Research conducted in the United States was predominant, and the participants' ages varied from 6 to 18 years old. Most interventions were implemented for 6 to 12 weeks, and pedometers seemed to be the most easily accessible device. Regarding intervention fidelity, a brief survey and interview were the most frequently used methods. However, there is a paucity of research reporting intervention fidelity on this topic, leading to uncertainty about research findings.

A Review of Health Wearable-based Physical Activity Interventions among Children and Adolescents

Introduction

Childhood and adolescence are essential life stages for youth to learn and sustain healthy lifestyles. Notably, these phases of life are critical as psychological and biological changes accelerate (WHO, 2017). In transitioning from adolescence to adulthood, individuals build similar lifestyle habits, including physical activity (PA) patterns (Beets & Pitetti, 2005). A physically active lifestyle is a well-known approach to cost-effectively preventing adverse physiological and psychological health outcomes (Kansra et al., 2021; Lavie et al., 2018; Powell-Wiley et al., 2021). In particular, it has been evident that physical inactivity is one of the major modifiable risk factors leading to obesity-related diseases (Fletcher et al., 2018). In response, it is proposed that children and adolescents participate in daily 60 minutes or more of moderate-to-vigorous physical activity (MVPA), including aerobic, muscle-strengthening, and bone-strengthening activities for at least three days per week (Department of Health & Human Services, 2018; Piercy et al., 2018). However, despite the importance of PA, only 24% of youth aged 6 – 17 years reported meeting the current guidelines (Katzmarzyk et al., 2018).

As a result, there is a continuous effort to develop effective PA interventions to improve youth PA participation. Specifically, since technology has become ubiquitous in our lives, integrating health wearables has been widely adopted to promote PA and health in research and clinical settings. Health wearables offer users the ability to track and record PA and other fitness-related parameters (Casado-Robles et al., 2022; Creaser et al., 2021). In detail, recent health wearable devices such as smartwatches (e.g., Apple watch, Fitbit) provide real-time personalized feedback to users on physiological and health metrics, including steps, PA time and intensity, heart rate, or energy expenditure. Accordingly, researchers and health professionals have been actively employing these unique capabilities lately to increase awareness of PA and motivate individuals to be physically active (Casado-Robles et al., 2022; Gao, 2017).

However, while extensive literature demonstrates promising evidence of the effects of health wearables on improved PA and other health-related outcomes (e.g., body mass index [BMI], aerobic capacity) among adults and clinical populations (Bice et al., 2016; Duscha et al., 2018; Ferguson et al., 2022; Nuss et al., 2021), there is a lack of health wearable-based intervention study targeting healthy children and adolescents. Thus, health benefits of health wearables in healthy youth are still unclear, and there is a need of exploring available evidence to guide future researchers and health professionals to develop improved PA programs. Furthermore, despite several researchers have attempted to analyze previous literature on the use of health wearable trackers to increase youth PA in recent years, to the best of our knowledge, none of the review papers have focused on intervention fidelity as part of the evaluation process of the available studies. This is particularly important, since the intervention fidelity of a study may be a significant factor that moderates, mediates, and impacts the variability of study findings (Craig et al., 2013; Lambert et al., 2017).

Within behavioral change research, intervention fidelity is often defined as the measure of the extent to which an intervention was designed and implemented as originally intended (Lambert et al., 2017). Therefore, intervention fidelity analysis is imperative to understand what specific factors are related to successful interventions (Hasson, 2015). Without sufficient evaluation of intervention fidelity, researchers and practitioners should be cautious when interpreting the intervention effects or adopting an intervention on a larger scale because of the possibility of variability in how a particular intervention plan was actually transferred to real-world settings (Toomey et al., 2020). At the same time, by ensuring that intervention was implemented with greater fidelity, researchers can gain greater confidence in their results (Bellg et al., 2004), and maximize the efficiency of research and its potential impact (Toomey et al., 2020). In addition to providing more definite study findings, assessing fidelity can help identify intervention components that facilitate replication and implementation in real-world settings (Lambert et al., 2017; Mars et al., 2013), as well as also helps ascertain the key components of theory-based interventions that link to an individual's behavior change (Bellg et al., 2004). Moreover, by monitoring and optimizing the study procedures, researchers can identify intervention elements that need to be refined to improve its delivery and statistical power (Bellg et al., 2004). In the absence of a proper evaluation of intervention fidelity, the core underlying mechanism for the behavior change will remain unclear.

Several frameworks to enhance intervention fidelity in research have been proposed and applied. For instance, in a conceptual framework proposed by Carroll et al. (2007) to evaluate implementation fidelity, the vital elements are adherence and moderators. Adherence refers to the extent to which intervention is delivered as intended and includes content, frequency, intervention length, and dose. In detail, the adherence degree may be moderated by the other factors: (1) intervention complexity; (2) facilitation strategies; (3) quality of delivery; and (4) participant responsiveness. In addition, Dusenbury et al. (2003) reviewed intervention fidelity based on five components: (1) adherence; (2) dose; (3) program delivery quality; (4) participant responsiveness; and (5) program differentiation. Finally, the NIH Behavior Change Consortium (BCC) developed a framework specifically to evaluate individual-level behavior change interventions (Bellg et al., 2004). The BCC conceptualized fidelity based on five factors: (1) study design; (2) provider training; (3) intervention delivery; (4) intervention; and (5) intervention enactment.

In this respect, this brief review aims to examine existing health wearable studies among youth to provide useful information for developing and adapting effective health wearable-based interventions. Specifically, this paper aims to explore the study characteristics (e.g., countries, participants, and intervention characteristics) and the process evaluation in experimental trials among children and adolescents on this topic. Finally, this paper will address future research needs in this area by exploring the limitations of previous study findings.

Method

This study reviews the evidence regarding the effects of health wearable-based PA studies among children and adolescents. A narrative review approach was adopted to develop a preliminary synthesis of the available literature, predominantly on addressing intervention fidelity within this topic. Specifically, this review investigated whether and how previous studies evaluated their intervention fidelity. Each article's fidelity components were checked based on but not limited to, criteria suggested in previously developed frameworks (Bellg et al., 2004; Carroll et al., 2007; Dusenbury et al., 2003).

Search Strategy

Articles for this narrative review were searched based on reference lists of included studies from the most recent previous systematic review papers regarding the effects of health wearables on youth PA (Casado-Robles et al., 2022; Creaser et al., 2021). In detail, to identify the latest systematic review literature, articles were searched using the Ovid Medline database. The search was carried out in the search type "title" using the following combination of keywords and Boolean operator strings: [(health wearable* OR activity tracker*) AND (adolescen* OR child*) AND (systematic review)]. Among four article results, two systematic review articles published in the most recent years (i.e., 2021 – 2022) were selected as sources for locating youth health wearable-based intervention studies. Then, all relevant publications for the current review were located among the reference lists from the two systematic review papers.

Eligibility Criteria

This review aims to collect articles based on the following inclusion criteria: (1) experimental design studies; (2) studies among healthy children and adolescents aged 5 to 18 years; (3) studies using health wearables as a medium to enhance PA or reduce sedentary behavior (SB); (4) studies with PA assessments as an outcome.

In terms of the eligibility criteria for included studies, both systematic reviews explored the intervention, acceptability, or feasibility studies that investigated the impact of health wearables on PA. However, specific criteria were not identical between the two systematic reviews. While Casado-Robles et al. (2022) only included intervention studies among healthy children and adolescents, Creaser et al. (2021) included all youth populations regardless of their diagnosed disease or conditions. Also, Creaser et al. (2021) examined studies published in a peer-reviewed academic journal, however, Casado-Robles et al. (2022) included dissertations or pilot studies as well. Moreover, Casado-Robles et al. (2022) had more strict inclusion criteria, excluding papers with only one experimental group or only post-intervention measurements and studies with only self-reported PA assessments.

Therefore, for this brief review, articles were excluded if they were not targeting healthy youth, not from peer-reviewed academic journals, not employing health wearables as a motivational medium, or not measuring PA objectively. Notably, this review considered obesity as a not severe chronic condition and included it in the review process. As a result, 45 publications were included in this literature review.

Results

Study Characteristics

Table 1 presents a summary of the study characteristics included in this review.

Countries

Most studies were conducted in the United States (n = 12), followed by the United Kingdom (n = 9) and Australia (n = 9). The remaining studies were conducted in Poland (n = 3), Ireland (n = 2), Finland (n = 2), Canada (n = 1), Caledonia on Lifou Island (n = 1), Iceland (n = 1), Italy (n = 1), Norway (n = 1), Mexico (n = 1), Singapore (n = 1), and Spain (n = 1).

Study Participants

Across the 45 included studies, the participants' ages ranged from 6 to 18 years. For this review, the definition of adolescence proposed by the World Health Organization (WHO) was used to distinguish between children and adolescents. According to the WHO, adolescence is the life stage between childhood and adulthood, age from 10 to 19. Based on this definition, 36 studies conducted interventions among adolescents (aged 10 to 19 years), six focused on children and adolescents (aged 5 to 18 years), and three focused only on children. Regarding gender, while 33 studies included both genders, seven were conducted with females, and five included only males. The participant size ranged from six to seven hundred. Based on power calculation from G*power software (Faul et al., 2007), a total sample size of 128 is suggested to detect sufficient statistical differences (F = 0.25, alpha = 0.05, power = 0.80). However, only 17 studies recruited more than 128 participants.

Study Design

Among 45 studies, 26 were randomized controlled trials (RCT) using school or class as a randomized unit. Quasi-experimental (n = 7) and 1-arm experimental (n = 7) were also commonly employed as the study design. Four were randomized controlled trials without a control group. One study used a 1-arm experimental trial and a quasi-experimental trial in phases 1 and 2, respectively. Regarding the PA measurement instrument, pedometers (n = 21) were mainly used to assess PA levels (i.e., steps). In addition, accelerometers (n = 15) were used to measure MVPA, and few studies used activity trackers such as Polar (n = 2) and Fitbit (n = 5) as measurement tools.

Table 1. Study Characteristics

Author	Year	Country	Sample size	Age	Gender
Baldursdottir et al. [1]	2017	Iceland	53	15 – 16	Mixed
Bronikowski et al. [6]	2016	Poland	196	11 – 17	Mixed
Buchele & Chen [8]	2018	US	116	10 –11	Mixed
Caillaud et al. [9]	2022	Australia	83	10 – 12	Mixed
Corepal et al. [12]	2019	UK - Northern Ireland	224	12 – 14	Mixed
Corr & Murtagh [14]	2019	Ireland	31	15 – 17	Female
Corr et al. [13]	2020	Ireland	17	12 – 16	Female
Dewar et al. [18]	2014	Australia	357	13 – 14	Female
Duck et al. [19]	2020	US	35	9 – 10	Mixed
Duncan et al. [20]	2012	UK - England	59	10 – 11	Mixed
Ermetici et al. [23]	2016	Italy	487	11 – 15	Mixed
Evans et al. [24]	2017	US	32	10 – 11	Mixed
Eyre et al. [25]	2016	UK - England	134	8 – 11	Mixed
Finkelstein et al. [28]	2013	Singapore	285	6 – 12	Mixed
Galy et al. [30]	2019	New Caledonia on Lifou Island	24	12 – 14	Mixed
Gaudet et al. [32]	2017	Canada	46	13 – 14	Mixed
Grao-Cruces et al. [33]	2016	Spain	142	10 – 11	Mixed
Groffik et al. [35]	2008	Poland	64	16 – 18	Mixed
Grydeland et al. [36]	2013	Norway	700	11 – 12	Mixed
Guagliano et al. [37]	2020	UK - England	82	7 – 11	Mixed
Hardman et al. a [39]	2009	UK - Wales	29	10 – 11	Female
Hardman et al. b [38]	2011	UK - Wales	386	7 – 11	Mixed
Hayes & Van Camp [41]	2015	US	6	8	Mixed
Horne et al. [42]	2009	UK - Wales	100	9 – 11	Mixed

Table 1. (continued)

Author	Year	Country	Sample size	Age	Gender
Jago et al. [43]	2006	US	473	10 – 14	Male
Jauho et al. [44]	2015	Finland	276	18 – older	Mixed
Kantanista et al. [46]	2017	Poland	82	16 – 18	Female
Larsen et al. [48]	2018	Finland	21	12 – 18	Female
Leinonen et al. [50]	2017	Australia	496	17 – 18	Male
Lubans & Morgan [52]	2008	Australia	116	13 – 15	Mixed
Lubans et al. a [54]	2009	Australia	124	14 – 15	Mixed
Lubans et al. b [53]	2011	Australia	100	15	Male
Lubans et al. c [55]	2016	Australia	361	12 – 14	Male
MacIas-Cervantes et al. [56]	2009	Mexico	76	6 – 9	Mixed
Morris et al. [60]	2019	UK - England	154	9 – 10	Mixed
Newton et al. [61]	2014	US	27	6 – 10	Mixed
Pittman [66]	2020	US	98	12 – 14	Mixed
Remmert et al. [69]	2019	US	20	12 – 13	Mixed
Routen et al. [70]	2014	UK - England	68	10 – 11	Mixed
Schofield et al. [71]	2005	Australia	85	15 – 17	Female
Shimon & Petlichkoff [72]	2009	US	113	12 – 14	Mixed
Shore et al. [73]	2014	US	92	11 – 12	Mixed
Smith et al. [74]	2014	Australia	361	12 – 14	Male
Thompson et al. [75]	2016	US	160	14 – 17	Mixed
Zizzi et al. [80]	2006	US	165	14 – 17	Mixed

Table 1. (continued)

Author	Year	Intervention Length	Intervention Design	PA Instrument	Wearable Type
Baldursdottir et al. [1]	2017	3 weeks	RCT	Pedometer	Pedometer
Bronikowski et al. [6]	2016	8 weeks	Randomized experimental trial	Survey	Garmin Vivofit
Buchele & Chen [8]	2018	4 weeks	Quasi-experimental trial	Fitbit Charge	Fitbit Charge
Caillaud et al. [9]	2022	5 weeks	Quasi-experimental trial	Accelerometer	Misfit Ray
Corepal et al. [12]	2019	8 – 14 weeks	RCT	Accelerometer	Fitbit Zip Pedometer
Corr & Murtagh [14]	2019	6 weeks	1 arm experimental trial	Survey	Pedometer
Corr et al. [13]	2020	6 weeks	1 arm experimental trial	Pedometer	Pedometer
Dewar et al. [18]	2014	12 months	RCT	Survey, accelerometers	Pedometer
Duck et al. [19]	2020	10 weeks	RCT	Accelerometer	Kid Power Band (activity tracker)
Duncan et al. [20]	2012	4 weeks	1 arm experimental trial	Pedometer	Pedometer
Ermetici et al. [23]	2016	2 years	Quasi-experimental trial	Pedometer	Pedometer
Evans et al. [24]	2017	4 – 6 weeks	1 arm experimental trial (phase 1); Quasi-experimental (phase 2)	Sense wear mini armband, Fitbit	Fitbit Zip Pedometer (phase 1), Fitbit Charge (phase 2)
Eyre et al. [25]	2016	6 weeks	Quasi-experimental trial	Pedometer	Pedometer
Finkelstein et al. [28]	2013	9 months	RCT	Pedometer	Pedometer
Galy et al. [30]	2019	4 weeks	1 arm experimental trial	Misfit Shine 2	Misfit Shine 2
Gaudet et al. [32]	2017	7 weeks	RCT	Accelerometer	Fitbit
Grao-Cruces et al. [33]	2016	6 weeks	Quasi-experimental trial	Pedometer	Pedometer
Groffik et al. [35]	2008	3 weeks	1 arm experimental trial	Pedometer, survey	Pedometer
Grydeland et al. [36]	2013	20 months	RCT	Accelerometer	Pedometer
Guagliano et al. [37]	2020	8 weeks	RCT	Accelerometer	Pedometer
Hardman et al. a [39]	2009	8 days	RCT	Pedometer	Pedometer
Hardman et al. b [38]	2011	16 weeks	RCT	Pedometer	Pedometer
Hayes & Van Camp [41]	2015	22 sessions (1 – 4 per week)	1 arm experimental trial	Fitbit	Fitbit
Horne et al. [42]	2009	2 weeks	RCT	Pedometer	Pedometer

Table 1. (continued)

Author	Year	Intervention Length	Intervention Design	PA Instrument	Wearable Type
Jago et al. [43]	2006	9 weeks	RCT	Accelerometer	Pedometer
Jauho et al. [44]	2015	3 months	RCT	Polar Active	Polar Active
Kantanista et al. [46]	2017	8 weeks	Quasi-experimental trial	Pedometer	Pedometer
Larsen et al. [48]	2018	12 weeks	1 arm experimental trial	Accelerometer, survey	Pedometer
Leinonen et al. [50]	2017	6 months	RCT	Polar Active	Polar Active
Lubans & Morgan [52]	2008	8 weeks	Quasi-experimental trial	Pedometer, survey	Pedometer
Lubans et al. a [54]	2009	10 weeks	RCT	Pedometer, survey	Pedometer
Lubans et al. b [53]	2011	6 months	RCT	Pedometer	Pedometer
Lubans et al. c [55]	2016	20 weeks	RCT	Accelerometer	Pedometer
MacIas-Cervantes et al. [56]	2009	12 weeks	RCT	Pedometer	Pedometer
Morris et al. [60]	2019	6 weeks	RCT	Accelerometer	Pedometer
Newton et al. [61]	2014	12 weeks	RCT	Pedometer	Pedometer
Pittman [66]	2020	10 weeks	Randomized experimental trial	Fitbit Surge	Fitbit Surge
Remmert et al. [69]	2019	12 weeks	Randomized experimental trial	Accelerometer, Fitbit Flex 2	Fitbit Flex 2
Routen et al. [70]	2014	3 weeks	RCT	Accelerometer	Pedometer, Actiwatch accelerometer
Schofield et al. [71]	2005	12 weeks	RCT	Pedometer, survey	Pedometer
Shimon & Petlichkoff [72]	2009	4 weeks	RCT	Pedometer	Pedometer
Shore et al. [73]	2014	6 weeks	RCT	Pedometer	Pedometer
Smith et al. [74]	2014	20 weeks	RCT	Accelerometer	Pedometer
Thompson et al. [75]	2016	12 weeks	RCT	Accelerometer	Pedometer
Zizzi et al. [80]	2006	3 weeks	Randomized experimental trial	Pedometer	Pedometer

RCT: randomized controlled trial

Intervention Programs

The length of the health wearable-based interventions varied considerably from eight days to two years. Notably, the most common duration of the interventions was six (n = 6) or twelve weeks (n = 6). The following prevalent intervention lengths adopted by the researchers were three, four, and eight weeks (n = 4 for each). Regarding integrated health wearable devices, most studies used pedometers as a motivational tool in the program with a goal-setting strategy (n = 34). Other devices employed were Garmin Vivofit, Fitbit (e.g., Charge, Flex 2, Surge), Polar, Misfit (e.g., Ray, Shine 2), Actiwatch accelerometer, and Kid Power Bands.

Intervention Fidelity

Table 2 presents a summary of the process evaluation and intervention fidelity strategies included in this review. Out of 45 included studies, 25 articles reported their plans to improve study procedures or intervention delivery. Many studies focused on reporting retention or adherence rates and program satisfaction. They used follow-up calls, an app dashboard linked with wearable devices, questionnaires, or interviews to determine the feasibility and/or acceptability of the interventions. However, of the 25 articles, not all studies specifically evaluated the intervention fidelity. Among studies that reported on the intervention fidelity plan, the type of measurements used for fidelity assessment included fidelity checklist, interview, and observational instruments (e.g., video recording, in-person observation). Moreover, most studies employed teacher training sessions to improve the quality of program delivery.

Table 2. Summary of Process Evaluation and Intervention Fidelity Strategies

Author	Process Evaluation/ Intervention Fidelity
Baldursdottir et al. [1]	Reminder message to use pedometer, step diaries, and submit data.
Bronikowski et al. [6]	N/A
Buchele & Chen [8]	Teachers reminded students to bring Fitbit
Caillaud et al. [9]	N/A
Corepal et al. [12]	Focus group interview (students, teachers) to assess acceptability and perception of the program.
Corr & Murtagh [14]	Feasibility (recruitment, data collection, acceptability, adherence) - e.g., recruitment records, focus groups, attendance rate, number of completion check
Corr et al. [13]	Feasibility (recruitment, acceptability of data collection procedures, resource evaluation, intervention provider ability) - e.g., survey and interviews, researcher records
Dewar et al. [18]	Teacher training, random observation
Duck et al. [19]	N/A
Duncan et al. [20]	N/A
Ermetici et al. [23]	N/A
Evans et al. [24]	Adherence rate - Number of days participants wore Fitbit (Fitabase)
Eyre et al. [25]	Encouragement for students to increase pedometer use
Finkelstein et al. [28]	Encouragement for families to attend sessions, reminders for pedometer use
Galy et al. [30]	Student feedback about online modules
Gaudet et al. [32]	N/A
Grao-Cruces et al. [33]	N/A
Groffik et al. [35]	N/A
Grydeland et al. [36]	Yearly teacher meeting, teacher training

Guagliano et al. [37]	Feasibility, acceptability (suggestions for improvement) - e.g., surveys and interviews
Hardman et al. a [39]	N/A
Hardman et al. b [38]	N/A
Hayes & Van Camp [41]	N/A
Horne et al. [42]	N/A
Jago et al. [43]	N/A
Jauho et al. [44]	N/A
Kantanista et al. [46]	N/A
Larsen et al. [48]	Feasibility, acceptability - e.g., follow-up calls and visits, satisfaction survey
Leinonen et al. [50]	Feasibility (use of features) - log-in check on database, surveys
Lubans & Morgan [52]	Intervention training
Lubans et al. a [54]	surveys (participation number, use of pedometer, participant's perception)
Lubans et al. b [53]	recruitment, retention, attendance, program satisfaction (survey)
Lubans et al. c [55]	Intervention observation
MacIas-Cervantes et al. [56]	N/A
Morris et al. [60]	Teacher training
Newton et al. [61]	N/A
Pittman [66]	N/A
Remmert et al. [69]	Acceptability (1:1 interview)
Routen et al. [70]	Reminder to wear pedomters by teachers
Schofield et al. [71]	Weekly group meetings (track program compliance, attendance log books, PA behavior review)
Shimon & Petlichkoff [72]	N/A
Shore et al. [73]	N/A
Smith et al. [74]	Teacher training and teachers evaluated one session, intervention dose/ session fidelity (observation, fidelity checklist)/ student attendance/ intervention compliance/ student satisfaction survey
Thompson et al. [75]	Survey, interviews at post-intervention
Zizzi et al. [80]	Perception (impact of pedometers on PA) - survey

Discussion

The current review addressed several key aims. Firstly, this paper reviewed previous health wearable-based articles to identify study characteristics. Secondly, this paper identified and summarized how preceding studies had measured intervention fidelity.

This review presented diverse characteristics of previous health wearable-based PA studies, which may be attributable to the variations in the study findings. For instance, we demonstrated differences in the characteristics of study participants (e.g., age, gender, race/ethnicity, SES) or study program (e.g., sample size, study design, intervention length, wearable device type) and outcome measurements (e.g., steps or MVPA). Based on observation of the study design, a quasi-experimental and cluster randomized trials seem to be the most prevalent study designs. Most studies were conducted in school settings, using the school or class as a randomization unit. This is anticipated because school is an integral channel and environment to promote PA for children and adolescents, as youth spend a considerable part of their waking time at school (Gråstén et al., 2021; van Sluijs et al., 2021). Furthermore, most studies used a pedometer as a motivational tool, and goal setting was prevalently incorporated as a motivational strategy (Casado-Robles et al., 2022).

Overall, evidence in evaluating the effectiveness of health wearables among youth is currently lacking because most concentration has been on the use of different health wearables in populations such as adults and clinical populations (McDonough, Su, et al., 2021). Only a paucity of high-quality, randomized studies has been completed on the use of motivational health wearable devices in PA behavior change interventions among healthy White children and adolescents. Thus, more information is required to develop and deliver health wearable technologies. Even though there is limited available literature evaluating the effectiveness of health wearables on PA among children and adolescents, moderate evidence suggests that pedometers can positively impact youth's daily steps (Casado-Robles et al., 2022).

However, the previous studies' findings need to be interpreted carefully because of the following limitations. First, limited research used health wearables as motivational tools (i.e., self-monitoring, self-regulation, real-time feedback) to foster youth's PA behavior change within an established theoretical framework. For instance, limited studies aimed to identify underlying mechanisms of PA behavior change. The importance of applying the theories has been reaffirmed for several reasons: (1) it helps researchers understand and predict the determinants of an individual's health behavior change; (2) it allows researchers to target proper determinants of health behavior to develop and implement effective strategies which systematically target determinants; and (3) it supports researchers to investigate successfully and organize the associations between variables and explain the observation following the intervention (Brug et al., 2005; Patten & Newhart, 2017; Pope et al., 2019). That said, applying theories and theoretical models is crucial when designing effective PA interventions to better understand the reasons for different PA levels of individuals and to guide PA promotion programs effectively.

Next, many studies had a limited number of participants, making the findings susceptible to weak renormalizabilty and bias. This review observed that out of 45 publications, only 17 studies had an appropriate sample size to detect sufficient statistical significance, and the follow-up rates were not favorable. Moreover, selection bias may occur because participants selected for analysis do not represent the enrolled population. Several studies also reported poor compliance with PA assessments which also can lead to misinformation bias. Furthermore, most school-based interventions employed health wearables outside physical education (PE) sessions without supervision, which may have contributed to poor intervention compliance.

Few studies incorporated sophisticated health wearable devices to encourage students to engage in a health-enhancing PA during PE classes. While many researchers used pedometers in PE classes, a pedometer can only provide step data, which has a limitation in providing users with prompt feedback about PA and physiological data (e.g., activity levels, calories burned, heart rate). In contrast, emerging health wearables (i.e., wearable sensors and activity trackers) have been popular for measuring and intervening in PA by providing users with metrics or feedback regarding their activities.

In recent decades, the body of evidence utilizing various health wearables has expanded rapidly with promising findings in health-related outcomes. Substantial evidence demonstrates that health wearables, when used in conjunction with behavior change strategies (i.e., self-monitoring and goal setting), can help increase physical activity and modest improvements in physiological outcomes such as reduced BMI, reduced blood pressure, and improved cardiorespiratory fitness, which might occur via an increase in physical activity (Ferguson et al., 2022). Therefore, health wearables that provide real-time PA intensity levels are warranted as a motivational tool.

Furthermore, PE is essential for youth to learn how to arrange for a physically active lifestyle. Among many factors tested to find an association with youth's PA levels during PE classes, fostering their enjoyment and motivation in PE was an effective strategy to promote PA (Liu et al., 2019; van Sluijs et al., 2021). Thus, it is imperative to develop enjoyable PE classes for children and adolescents to overcome barriers to PA participation and reach health-enhancing physical activity levels (MVPA). In light of the substantial health benefits of wearable devices, studies that include the motivating characteristics of health wearable technologies (i.e., real-time and summarized feedback for self-monitoring and self-regulation) have the potential to facilitate students' enjoyable PE learning experience, and further encourage students' health-enhancing PA levels.

In addition, there was little effort to recruit diverse study cohorts, including underserved minority children and adolescents. This is problematic because children and adolescents in underserved urban inner cities rely heavily on in-school PE programs for structured PA opportunities because of the unsafe insecure built environment and limited access to PA/exercise facilities (Bantham et al., 2021; McDonough et al., 2021). Thus, more studies targeting underserved youth are warranted to help all children and adolescents to have equal PA opportunities.

Lastly, there is a lack of studies that emphasize internal and external validity, and most studies predominantly aimed to investigate the effectiveness of the interventions without considering intervention fidelity as part of process evaluation. Consequently, a knowledge gap exists regarding the health benefits of health wearables in healthy youth, as many studies did not describe whether the interventions were delivered as intended. Thus, it is imperative to consider intervention fidelity when designing and delivering an intervention program. Notably, Craig et al. (2013) highlighted that researchers targeting school settings need to determine the extent to change or adaptation allowed in implementation compared to the original protocol when adopting diverse local circumstances.

These limitations leave little evidence on the effectiveness of health wearable technology-based PA interventions among underserved children and adolescents during PE classes. Accordingly, given the growing body of literature showing the impact of health wearable technologies on PA behavior change, it is imperative to bridge the gap between previous literature by expanding the use of novel wearable activity trackers among underserved youth in PE classes to improve PA. Additionally, future studies need to be built upon theoretical frameworks and identify underlying mechanisms of PA behavior change (e.g., psychosocial factors, phycological factors) among children and adolescents. Of note, experimental studies should consider specific strategies to enhance intervention fidelity in research and address intervention fidelity assessment in their paper. By monitoring and optimizing the study procedures, researchers can identify intervention elements that need to be refined to improve intervention delivery and statistical power (Bellg et al., 2004). Moreover, considering intervention fidelity also helps ascertain the key components of theory-based interventions that link to an individual's behavior change (Bellg et al., 2004). However, without a consideration of the intervention fidelity, the core underlying mechanism for the behavior change will remain unclear. In short, intervention fidelity assessment provide valuable insight into why an intervention fails or succeeds and how it can be optimized, which can further improve the internal and external validity of the research.

Strengths and Limitations

This review paper sheds light on reporting the overview of intervention fidelity of published health wearable studies among healthy youth. This paper is the first attempt to identify and synthesize information about intervention fidelity as part of the evaluation process. We anticipate provoking researchers and health professionals on this topic about the essentials of assessing the fidelity of intervention components. In addition, this paper presents limitations and future directions for PA programs using wearable technologies in children and adolescents. Nevertheless, our observations should be considered with caution. Despite our effort to minimize biases, there is a potential for selection information bias due to the nature of the unsystematic approach which has been adopted in this paper. Therefore, readers should take this drawback into account when interpreting this article.

Conclusions

The current review addresses valuable information on health wearable-based PA intervention. While several researchers have investigated the effectiveness of using wearables in increasing youth PA, there is still a lack of studies on this topic compared to adults and the clinical population. Additionally, this paper emphasizes the importance of sufficient evaluation of intervention fidelity to understand what specific factors are related to successful intervention and facilitate replication and implementation of successful intervention. Lastly, a quantitative systematic literature review on this topic is warranted in the future.

Funding Sources

This study did not receive any grants.

Acknowledgement

We have no conflict of interest to disclose.

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