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Review

New Technologies for Promoting Physical Activity in Healthy Children and in Children with Chronic Respiratory Diseases: A Narrative Review

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Abstract: Physical activity (PA) is proven to benefit children and adolescents in several ways. New technologies may provide children with stimulating modalities for organizing their leisure time, accessing fitness programs, and obtaining daily goal reminders and peer support. Due to the current COVID-19 pandemic, following WHO recommendations for PA is difficult for many children, especially for those living in urban areas. Therefore, the use of digital tools to support and maintain PA could be useful in healthy children, as well as in those with chronic respiratory diseases (CRDs). This narrative review aims to summarize the most recent evidence about the role of new technologies in promoting PA in healthy children and in those with CRDs, in supporting PA during the COVID-19 pandemic, and in enhancing psychological wellbeing in this age group. The use of technological devices for promoting PA, such as web/mobile apps and games, has been proven to be effective both in healthy children and in those with CRDs. In conclusion, new technologies are very promising in terms of feasibility, acceptability, and efficacy in promoting PA. Further studies are required to evaluate the long-term health benefits of using these technologies.

Keywords: adolescents; children; chronic respiratory diseases; COVID-19; digital health; e-health; physical activity; physical exercise; psychological wellbeing

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1. Introduction

In children and adolescents, physical activity (PA) is proven to benefit cardiometabolic health, motor skill development, bone density, quality of life, and psychological wellbeing [1]. Importantly, available evidence suggests that many health benefits persist into adulthood [2]. Conversely, sedentary behaviour is associated with adverse outcomes, such as increased adiposity and impaired overall health [3].

According to WHO 2020 guidelines on PA and sedentary behaviour, children and adolescents should play a minimum of about 60 min/day of moderate-to-vigorous mostly aerobic PA (MVPA) [4], or an equivalent of about 12,000 steps per day [5]. In addition, they should limit the amount of sedentary time, particularly watching TV and playing video games [4]. Nonetheless, generally insufficient levels of PA have been reported in children and adolescents across the world [6], probably because international recommendations are not well supported for implementation in real life.

Digital tools such as gaming consoles, smartphones, and social media may be useful to promote PA [7,8]. Indeed, they may provide children with stimulating modalities for organizing leisure time, accessing fitness programs, and obtaining daily goal reminders

and peer support. In particular, gamification may improve user experiences and motivate children to participate in PA.

Establishing creative ways to engage children and adolescents in PA could include participating in online physical education classes or physically active gaming. At the inter-individual level, social media could support children and their families to engage in MVPA (e.g., running, biking, swimming), while adolescents could use activity trackers/online fitness challenges against their friends [9].

Due to the current COVID-19 pandemic, adhering to WHO recommendations for PA could be difficult for many children, particularly those living in urban areas. The ordinary daily routine dramatically changed during home confinement, with an increased risk of unhealthy lifestyles [10]; in particular, a general decline in PA has been reported. While social distancing and the obligation to stay at home potentially decrease opportunities for PA, the promotion of home-based activities for increasing PA has become essential for improving health. In this regard, the use of digital tools to support and maintain PA could be particularly useful, especially for children with disabilities and special health needs.

Available evidence on the efficacy of new technologies for increasing PA is not very strong in children, especially in those with chronic respiratory diseases (CRDs). This is mainly due to small sample sizes and heterogeneity in study designs and populations. To summarize the knowledge and to identify the research gaps, we aimed to review the current evidence on the role of new technologies in promoting PA in healthy children and in those with CRDs, in supporting PA during the COVID-19 pandemic, and in enhancing psychological wellbeing in this age group.

2. Methods

On 31 May 2021, we searched PubMed, using the following keywords, separately and in combination: children, adolescents, digital health, e-health, physical activity, physical exercise, healthy, chronic respiratory diseases, COVID-19, psychological wellbeing. An example of keyword combination was the following: "(children OR adolescents) AND (digital health OR e-health) AND (physical activity OR physical exercise) AND (healthy OR chronic respiratory diseases OR COVID-19 OR psychological wellbeing)". The inclusion criteria were: (1) articles introducing and/or testing new technologies for promoting PA in healthy subjects or subjects with CRDs up to 18 years; (2) reviews, protocols, trials, observational studies and feasibility studies; (3) publication year from 2011 to 2021; (4) English language. The exclusion criteria were: (1) out of topic; (2) editorials, abstracts, letters, and case reports. Articles concerned with COVID-19 pandemic and psychological wellbeing were identified and described in separate sections. For included articles, we screened the reference lists and searched for potentially relevant citing articles in Scholar.

Two reviewers (V.M. and S.L.G.) screened the articles for relevance based on titles and abstracts. The same reviewers screened the full texts of potentially eligible articles. Figure 1 summarizes the study selection process. We identified 172 articles through the four electronic databases and 67 of them were identified as potentially eligible based on evaluation of titles and abstracts. Of them, 52 were excluded following full-text evaluation (out of topic). Therefore, 15 articles were included in this review: seven concerning healthy children [11–17], three concerning children with CRDs [18–20], two concerning COVID-19 pandemic [21,22], and three focused on psychological wellbeing [23–25].

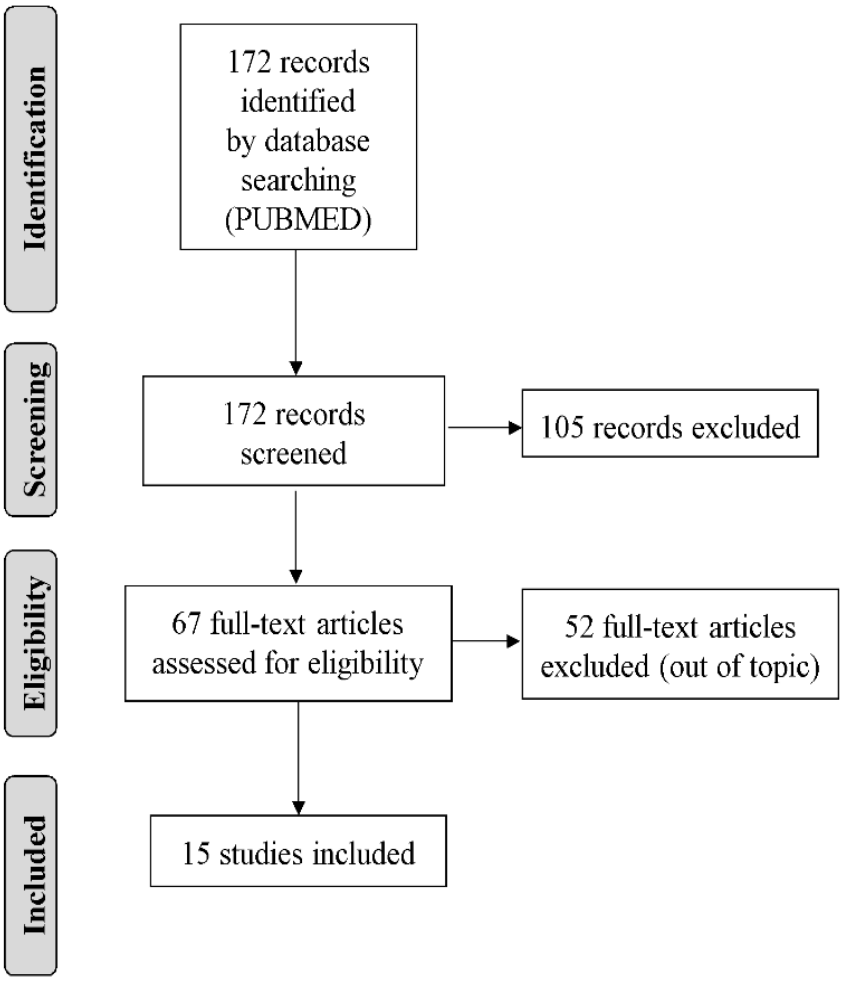


Figure 1. Flow diagram showing the study selection process.

3. New Technologies for Promoting Physical Activity in Children

Technology oriented to promote PA in paediatric age includes traditional and more recently developed tools. Short text messages (SMS) sent to parents' mobile phones are one of the most traditional systems for encouraging children's PA and motivating parents to foster behavioural changes towards an active lifestyle in their children [26]. Another traditional way of exploiting technology to promote PA is represented by self-monitoring devices such as heart rate (HR) monitors, pedometers and accelerometers, which can motivate to increase PA by providing instantaneous feedbacks [27].

In the very last years, technology advancements have allowed the development of innovative digital tools, which may be grouped into two categories: web/mobile apps and games (Table 1). The most recent smartphone app released is called the "Recess and Exercise Advocacy Program" (REAP). The live-streaming platform of REAP allows users to record and share short videos and photographs related to their PA. Thanks to an integrated system, users are alerted by text messages to log into the REAP app to participate in live streaming [21]. Similarly, SanoYFeliz is a web app allowing adolescents to access the social network (add friends, comment on publications, create events, and get reward points) and to receive personalized advice on nutrition and PA [28].

Zombies, Run! is an immersive audio augmented-reality (AR) mobile app for adolescents combining exercise and a post-apocalyptic narrative radio story [16]. Indeed, the association of narratives in the games may induce a positive attitude toward performing healthy behaviours, potentially promoting the development of autonomous motivation to complete the game and adopt the behaviour promoted in the game [14,17].

Table 1. Summary of the very last technologies aiming to promote PA in children and adolescents.

Tool Name	Category	Target Age	Features	Reference
REAP	Mobile APP	12–13 years	- Live-streaming platform - Recording and sharing videos and photographs - Text messages alerts	Zheng et al., 2021 [21]
SanoYFeliz	Web APP	Adolescents (mean age 12 years)	- Access to social network - Advices on nutrition and PA	Benavides et al., 2021 [28]
Zombies, Run!	Mobile APP	13–16 years	- Audio augmented-reality - Exercise and post-apocalyptic narrative story	Faric et al., 2021 [16]
Moovosity™	Mobile APP	3–6 years	- Digital library of games in five domains - Video demonstrations and step-by-step instructions - Sharing achievements with family and friends through SMS	Trost et al., 2021 [29]
iEngage	Mobile APP	12–14 years	- Modules of activities, quizzes, and PA sessions	Galy et al., 2019 [12]
Mini Movers	Web APP	2–4 years	- Text message program for parents - Active play ideas - Monitoring PA - Individual goals	Downing et al., 2018 [15]
BOOSTH	Game	7–12 years	- Activity tracker through a mobile app - Setting achievable goals and monitoring progress - Gaming incentives - Group competitions	Ten Velde et al., 2020 [30]
Kung Fu for Kinect	Game	8–12 years	- Whole-body movements via a Kinect sensor on a gaming console	Sousa et al., 2020 [14]
FIT Game	Game	11–12 years	- Science-fiction narrative game - Comic book format	Joyner et al., 2019 [11]

The Moovosity™ [29] app is designed as a digital library of games developed to be fun, engaging, and to establish a positive attitude towards PA. The games are organized into five domains: fitness, rhythm, agility, coordination, and balance. The app provides video demonstrations and instructions on how to play the games. Children are rewarded with percentage points, where 100% corresponds to the recommended 60 min of daily MVPA [4]. Children can share their achievements with family and friends through an SMS text function.

The iEngage is an e-health educational program developed for smartphones and tablets; it includes eight 1-h modules within which users carry out activities, quizzes,

and brief specialized PA sessions focused on sprints, jumping, walking, running, squats, sit-and-reach, or push-ups [12].

Downing et al. realized the "Mini Movers", a text message-delivered program aiming to inform and support parents through practical ideas and suggestions for promoting PA among their children aged 2–4 years. In this case, text messages were delivered using a web platform and were designed to provide active play ideas, monitoring PA and encouraging achievement of individual goals [15].

Among games, BOOSTH is an online arcade game that, by interfacing with an activity tracker through a mobile app, stimulates PA and contributes to positively changing the attitude toward PA in children aged 7–12 years. The use of activity trackers helps children to set achievable goals and to monitor their progress toward the goals. Depending on the magnitude of PA levels, children are rewarded by online playtime and gaming incentives such as unlocked levels and special features to increase the interest and enthusiasm of the child. In addition, an interactive version of the game allows children to participate in competitions between groups, so-called "BOOSTH battles". Children can create their personalized battles in the BOOSTH app [30].

Kung Fu for Kinect AVG (Active Video Game) involves whole-body movements via a Kinect sensor on a gaming console. Children could see their bodies on the screen and fight enemies with a variety of intermittent and spontaneous movement patterns and skills, such as jumping, punching, and kicking [14].

Field Intensive Trainees (FIT) is a science-fiction narrative game used to increase the fruit and vegetable consumption of schoolchildren. Children are tasked with finding and capturing three villainous members of the Vegetation Annihilation Team before they can cause planetary destruction. Once PA goals are met, a new episode of the FIT Game is presented in a comic book format [11].

System-human interfaces represent the new frontier for the promotion of PA for the next future, as already proven in other healthcare contexts [31]. In this regard, a robotic-assisted exercise coach was recently tested in adolescents by Barwise et al. [32]. Through this prototype, coaching is delivered via a remotely controlled tablet placed on a mobile robotic wheelbase. During the exercise session, the prototype can move around the child while providing instructions, corrections, and support.

3.1. New Technologies to Promote Physical Activity in Healthy Children

Varma et al. [33] identified childhood (6–11 years) and adolescence (12–19 years) as the age groups with the highest risk for decline in PA levels and in MVPA. Therefore, technological devices can represent innovative and targeted health interventions for motivating positive changes in these vulnerable subjects. A summary of studies adopting new technologies for promoting PA in children and adolescents is reported in Table 2.

At school, mobile and web apps, also in combination with activity trackers (wearable devices designed to monitor PA levels), can be successfully used as educational play tools for increasing children's PA. Joyner et al. [11] carried out a 40-day pilot study (in four phases: baseline 1, day 1–10; FIT Game phase 1, day 11–20; baseline 2, day 21–30; FIT Game phase 2, day 31–40) on 29 healthy children. They aimed to test the FIT Game in combination with an accelerometer recording daily step counts, worn at school for 20 min a day. They found a behavioural change towards an increase in PA only during the FIT Game phases, demonstrating the usefulness of this technology in reducing dropout rates towards PA. Indeed, during the FIT Game phases, children received objectives that helped them increase their PA more than in baseline phases. In particular, from Baseline 1 to FIT Game phase 1, PA increased significantly by a median of 1073 steps per child per day ($p < 0.001$). From FIT Game phase 1 to Baseline 2, the average number of steps significantly decreased (step reduction not reported, $p < 0.001$). When the game resumed in FIT Game phase 2, PA significantly increased again, by a median of 658 steps per child per day ($p < 0.001$).

Table 2. Summary of studies on new tools for promoting PA in healthy children and adolescents.

Reference	Country	Target Age	Results	Comments
School setting				
Joyner et al., 2019 [11]	USA	11–12 years	Physical activity increased significantly during the FIT Game phases.	The study demonstrated the usefulness of an exergame for increasing PA in the short term.
Galy et al., 2019 [12]	New Caledonia	12–14 years	PA increased during the program, particularly in less active adolescents. The tool helped to reach recommended PA levels.	An integrative approach combining educational programmes and digital technologies improves PA behaviours in the short term.
Garde et al., 2016 [13]	Canada	11.3 years (mean)	Active time increased during the program, particularly among children with a higher BMI z-score. The tool helped to reach recommended PA levels.	Mobile exergames in adolescents could be useful tools for promoting PA in the short term and to prevent obesity.
Home setting				
Farič et al., 2021 [16]	England	13–17 years	Virtual reality (VR) exergaming was positively correlated with PA.	VR exergaming has the potential of a public health intervention designed for the short-time engagement of adolescents in PA.
Sousa et al., 2020 [14]	USA	8–12 years	Playing video games with narrative immersion was positively correlated with PA.	Narrative immersion acts as a key mediator in increasing PA in the short term.
Lu et al., 2019 [17]	USA	8–12 years	Narrative embedded in active games may be positively correlated with PA.	Narratives embedded in active games can be a key mediator in increasing PA in the short term.
Downing et al., 2018 [15]	Australia	2–4 years	Text messages helped children spend less time in sedentary activities.	Smartphones and tablets may be effective for increasing PA in the short term.

Galy et al. [12] carried out a 4-week exploratory study on 24 adolescents aiming to test the iEngage app. They found that using the app improved PA during the program, especially among less active adolescents, who showed a 27% increase in adherence to international recommendations for PA intensity [4].

These results were in line with Garde et al. [13], who carried out a 4-week randomized crossover study on 42 healthy students. They aimed to test the effectiveness of MobileKids Monster Manor (MKMM), a mobile-based exergame, in a school setting. Study participants underwent a baseline phase (both arms), a game intervention (arm 1)/control phase (arm 2), a washout phase (both arms), and a control (arm 1)/game intervention phase (arm 2); each phase lasted 1 week. All participants were provided with an activity monitor to record steps and active minutes. MKMM was used during intervention weeks, when children were asked to play to their liking. During intervention phases, a significant increase was observed in the number of steps per day with respect to the control phases (2934 steps, $p = 0.0004$), and in the number of active minutes per day with respect to the baseline phases (46 min, $p = 0.001$). Moreover, MKMM was more effective among children with a higher body mass index (BMI), suggesting that mobile exergames could be useful for promoting PA in these subjects.

New technologies have also been developed for supporting parents at home, in order to induce positive changes and to reduce the time spent by their children in sedentary activities. In the pilot study by Sousa et al. [14], lasting 4 months, 22 children were randomly assigned to two conditions, i.e., playing video games with or without narrative

strategies. Narrative immersion was positively and moderately correlated with MVPA (r = 0.52, $p = 0.01$) and average HR (r = 0.43, $p = 0.05$) during the game.

Downing et al. [15] aimed to test the feasibility and effectiveness of a text message program delivered through a web app in 57 parents of preschool children. The intervention lasted 6 weeks. Text messages helped parents increase knowledge, set goals, and provide reinforcement to engage children in PA. The Authors found that children in the intervention group spent less time (−35.0 min) in sedentary activities than in the control group.

Serious games and narrative exergames [14,16,17] may be particularly suitable for children as these interventions use interactive and visual strategies that adapt to the learning style of "digital natives".

3.2. New Technologies to Promote Physical Activity in Children with Chronic Respiratory Diseases

In children and adolescents with CRDs, such as asthma and cystic fibrosis (CF), symptoms can lead to reduced levels of PA. Data about the comparison of PA levels between children and adolescents with CRDs and their healthy peers are conflicting [34]. Some authors have suggested that children and adolescents with CRDs are engaged in less PA [35]; conversely, other authors reported only a slight reduction in MVPA, and a similar sedentary time compared to healthy controls [34,36].

In asthmatic subjects, PA can help improve disease control, cardiopulmonary fitness, and quality of life by reducing airway inflammation and bronchial reactivity [37]. Asthmatic children with good cardiorespiratory fitness require less ventilation per minute, leading to an improvement in bronchial reactivity. In addition, regular PA leads to a reduction in airway inflammation [38]. On the other hand, in children with poor asthma control, vigorous physical training can trigger bronchoconstriction, but when appropriate precautions are taken, MVPA can be extremely safe [39].

Carrying out PA by taking advantage of new technologies can be considered a potentially innovative alternative to traditional exercise programs for improving asthma control. Gomes et al. [18] hypothesized that an AVG system could be as effective as treadmill training for improving clinical control and aerobic fitness in children with asthma. Therefore, they aimed to determine whether aerobic exercise involving the AVG system could improve asthma control, airway inflammation, and exercise capacity in children with moderate-severe asthma. The study involved 36 children diagnosed with moderate-severe asthma and treated with budesonide and long-acting β_2-agonists. Children were clinically stable within the previous 30 days. Patients were randomly assigned to a video game group (VGG, 20 children) or treadmill group (TG, 16 children). For both groups, anthropometric data, body composition (lean mass, fat mass, waist circumference, BMI), spirometry parameters, fractional exhaled nitric oxide (FeNO), asthma control (Asthma Control Questionnaire, ACQ), and energy expenditure were monitored before and after the exercise protocols. HR and oxygen saturation were monitored during the training period lasting eight weeks and involving two 40-min weekly sessions (5-min warm-up, 30-min workout, and 5-min cool-down). Improvements occurred in both groups in terms of asthma control and HR. Concerning cardiovascular variables, VGG reached a greater percentage of the predicted maximum HR than TG in the post-training evaluation ($p < 0.01$). Furthermore, a FeNO reduction was found in VGG ($p < 0.05$). The average energy expenditure at rest and during PA was similar for both groups, while the maximum energy expenditure was higher in VGG than in TG ($p < 0.05$).

Children with CF are characterized by reduced mucus clearance leading to a reduction in muscle function with reduced resistance to physical exercise [40,41]. In these patients, PA has potential therapeutic effects on exercise capacity, lung function, peripheral muscle dysfunction, and health-related quality of life.

Del Corral et al. [19] evaluated the effectiveness of an exercise program at home using an AVG platform on 39 clinically stable children with CF aged 10–12 years. The training modality was aimed to improve exercise capacity and muscle strength. The Authors proposed a 6-week home training protocol consisting of 30- to 60-min sessions,

5 days a week, using a Nintendo Wii™ platform with the EA SPORTS™ ACTIVE 2 game, involving activities such as running, squatting, lunging and curls for biceps. The game is supervised by a virtual personal trainer and includes an HR monitor. Thirty-nine children were randomized to a training group (AVGG, 19 children) or a control group (CG, 20 children). Exercise capacity was measured through the 6-min walking test (6MWT) and the modified shuttle walking test. Muscle strength was measured using the horizontal jump test, medicine ball throw and handgrip strength. All assessments were made at baseline, after the intervention period and 12 months after. The change in all the above outcomes at the post-intervention assessment favoured the AVGG. Such positive results may be ascribed to the training intensity (5 days a week for 6 weeks), the specificity of the AVG, and the inclusion of aerobic exercise conservation, muscle strength, body endurance and flexibility in the training protocol. In summary, training using AVG at home has produced positive short- and long-term effects in young patients with CF. However, long-term adherence to the home program progressively decreased.

Previously, Del Corral et al. [20] demonstrated the usefulness of video games in children with CF as tools to be used in a training program in a CF ward for improving the exercise capacity of these patients. They carried out an observational study on 24 patients aged 7–18 years. They aimed to compare physiological responses, such as oxygen uptake (VO_2), minute ventilation (VE), HR and respiratory rate (RR), obtained during three AVGs for Nintendo Wii™ and during a 6MWT. All patients were clinically stable and received routine patient management including inhaled antibiotics for respiratory infections, chest physiotherapy, and nutritional supplementation. Participants performed the three AVGs in a random order for two days, with a minimum of 30 min of rest between them. The three AVGs were: (1) Wii Fit Plus (Wii-Fit), with aerobic exercise that mobilizes arms and legs; (2) Wii-Active (Wii-Acti), with aerobic training to improve muscle strength, body endurance and flexibility; (3) Wii Family Trainer (Wii-Train), with aerobic training through the FAMILY TRAINER EXTREME CHALLENGE© game, which provides a full-body workout training. The AVGs were well tolerated by CF patients, who were all compliant with the three Wii™ modes. During all AVGs and 6MWT, VO_2 reached a plateau from the 3rd min. Compared to 6MWT (1024.2 $\pm$ 282.2 mL m^{-1}), Wii-Acti (1232.2 $\pm$ 427.2 mL m^{-1}) and Wii-Train (1252.6 $\pm$ 360.2 mL m^{-1}) achieved higher VO_2 levels during the last 3 min ($p < 0.0001$ in both cases), while Wii-Fit (553.8 $\pm$ 113.2 mL m^{-1}) achieved significantly lower levels of VO_2 ($p < 0.001$). Similar effects were observed for VE. No differences in dyspnoea and oxygen saturation were observed between the different modes. All the modes tested imposed a constant load but were associated with different physiological responses reflecting the different intensities imposed. Wii-Acti and Wii-Train required a significantly higher (about 20%) metabolic demand than the 6MWT ($p < 0.0001$). This study confirms that AVGs can be effective training modalities in this patient group.

3.3. New Technologies to Promote Physical Activity in Children during the COVID-19 Pandemic

Confinement measures adopted during the COVID-19 pandemic have caused a substantial decrease in PA levels across all ages. However, this was mostly observed in some risk groups including children and adolescents [10]. Emerging evidence is available on the promising role of digital devices in children and adolescents during this pandemic time.

During the lockdown in Italy (April–May 2020), an online survey was carried out in 1860 children and adolescents aged 12–18 years. The survey showed that 84.5% of the participants regularly practised PA at home. About 30% spent 1–3 h per week in PA, predominantly using technology (computers, smartphones, tablets). In particular, time spent using technology for educational purposes, including PA, was >6 h a day for 49.7% of the participants, suggesting that digital devices played a crucial role for youths who started playing PA at home [42].

A digital behaviour change intervention was tested in 896 Chinese children (mean age 13.5 years) during home confinement due to the COVID-19 pandemic. Participants were randomized to receive: (1) an online health information session by teachers and text

messages to participate in broadcast exercises programs at home (control group); (2) an online health information session by teachers plus access to a live-streaming app allowing peer sharing of promoted PA (intervention group). Participants in the intervention group were prompted by text messages to log into the app to participate in live streaming or posting their exercises through videos and photographs. After two weeks, the intervention group showed a significantly greater change in self-reported anxiety scores than in the control group ($p = 0.02$), demonstrating the potentially relevant role of digital technology in improving health outcomes by promoting PA. This issue is of crucial importance given the psychological impact of COVID-19 pandemic on vulnerable individuals like children and adolescents during the period of home confinement [21].

In line with these findings, a web-based survey conducted in May 2020 among 1607 students from 267 Chinese cities and including 20 adolescents, showed that performing regular PA during the pandemic was associated with a lower risk of mental disturbance. This was particularly evident among participants who exercised more than 1–2 times a week, who had an exercise duration >1 h, and who had >2000 average pedometer steps. However, more than 50% of respondents did not want to experience PA online. Moreover, technical problems were frequently reported (67.6%), including network instability and poor familiarity with software. Furthermore, 29.9% reported a lack of interaction with the teacher. These findings suggest that web-based PA for students is still not satisfactory. Technical problems and poor interactions are the main issues that should be faced in order to improve the experience of PA at home [43].

Home confinement owed to the current pandemic may be particularly detrimental in children with physical disabilities, decreasing opportunities to socialize with peers and to engage in PA, thereby worsening their functional decline. Recently, telerehabilitation, i.e., the delivery of rehabilitation services via telemedicine, has been proposed as a promising strategy to maintain PA during the pandemic [22]. Telerehabilitation encompasses a range of virtual reality technologies including commercially available video games and custom-made applications, which can offer innovative solutions for reducing the impact of long-term interruptions in rehabilitation services. Virtual reality in the context of rehabilitation programs uses platforms involving real-time simulation allowing the user to interact via multiple sensory channels [44]. Previous studies demonstrated the feasibility of in-home rehabilitation programs using such technology in children with physical disabilities [45,46].

3.4. New Technologies for Enhancing Psychological Wellbeing through Physical Activity in Children

In paediatric age, PA has been shown to have positive effects on psychological wellbeing, a multidimensional concept including self-esteem, self-efficacy, autonomy, self-concept, motivation, concentration, learning abilities, and social behaviour [47,48].

In healthy children and adolescents, a recent systematic review on thirty-six studies with a total sample of 38,724 participants (including adults) demonstrated that PA carried out through AR mobile games (Pokémon GO) is associated with increased life satisfaction, happiness, and vitality. Moreover, it was associated with several cognitive outcomes such as verbal working memory, selective attention, creativity, and concentration levels [23].

In a systematic review on the benefits of AVGs for PA in children and adolescents, Merino-Campos and Fernandez considered 100 articles between 2010 and 2015. They aimed to verify the improvement of attitudes, intellectual skills, knowledge, motor skills and physical properties associated with PA. The review showed that AVGs for PA had been able to improve social interaction, mood, and self-esteem in the short term. They also helped to develop spatial skills, increase participants' motivation and enjoyment of PA, and increase cognitive control and attention [24]. Moreover, a review by Staiano and Calvert showed short-term beneficial psychological effects of exergames among youths in terms of increased self-esteem, improved social interaction, mood, motivation, cognitive and academic outcomes (attention, visual-spatial skills, academic performance) [25].

The issue of increasing PA through new technologies may be particularly relevant in children with CRDs who may often have an impaired quality of life with associated

psychosocial disorders (i.e., anxiety, depression, poor social relationships and cognitive functions) [49]. In CRDs, specifically asthma and CF, it has been shown that the use of new technologies for increasing PA allows the achievement of positive health outcomes in terms of symptom control, quality of life, adherence to treatment [18], but there is no research focused on psychological wellbeing effects.

4. Discussion

New technologies such as web/mobile apps and AVGs can represent innovative and targeted health interventions to reduce sedentary behaviours, to improve adherence to international recommendations for PA, and to induce positive behavioural changes in healthy children and in those with CRDs. Moreover, emerging evidence highlighted the role of new technologies in counteracting the overall declining trend in PA observed in children and adolescents during the COVID-19 pandemic. Finally, although technological advances may contribute to increasing the "screen" time, recent studies have highlighted the efficacy of digital tools in increasing PA, with associated benefits on psychological wellbeing and psycho-physiological factors related to the body/motor experience (Figure 2). New technologies have been shown to be very promising in terms of feasibility and acceptability.

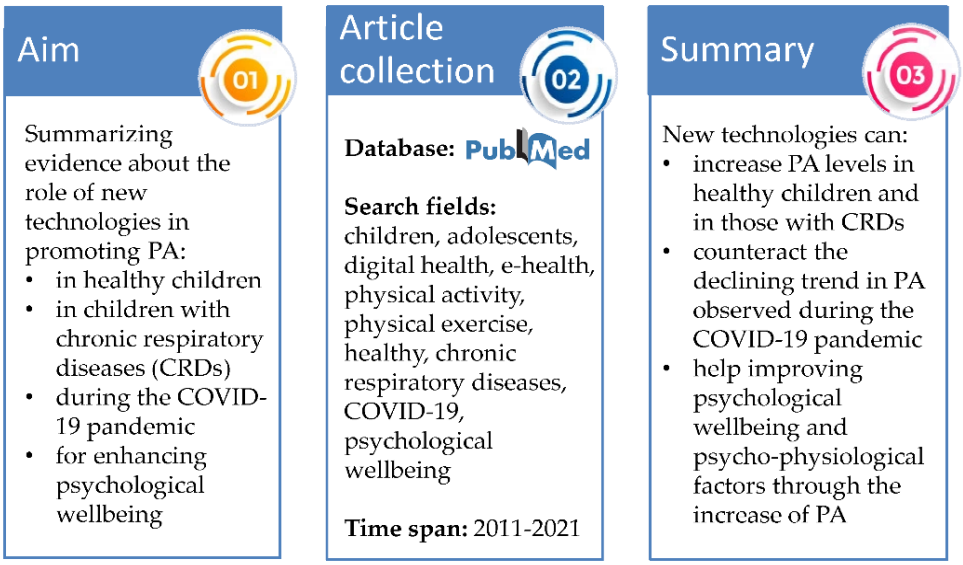


Figure 2. Conceptual frame representing the three steps characterizing this review.

More traditional self-monitoring devices (activity trackers), such as pedometers and accelerometers, can be successfully used in combination with innovative web/app digital tools and mobile games to increase children's PA. Indeed, such devices can increase participants' acceptance and help children to set achievable goals and to monitor their progress toward the goals (e.g., recommended PA levels) by providing instantaneous feedbacks [50].

Concerning implementation into practice, the potential of new technologies to promote PA seems to have been overlooked. In this regard, future directions of innovation should focus on the training and evaluation of learning systems (based on big data and machine learning approaches) in order to adapt innovative tools to the needs of different users, according to age, health status, contexts, and objectives to be achieved. This would open the way for increased sustainability of health services, by enhancing the interaction between health professionals, patients and other people (families, peers, citizens, institutions, etc.) [51]. Moreover, possible negative effects of the use of new technologies in promoting PA in healthy children and those with CRDs should be evaluated.

Identified research gaps include a lack of long-term interventional studies (6–12 months) aiming to assess the ability to produce positive behavioural changes in the long term. Indeed, previous research suggests that long-term engagement in exergaming may be difficult to

achieve, especially in children with CRDs [7]. Moreover, there is a lack of standardized methods for establishing frequency, duration, and type (flexibility, resistance, endurance) of PA programs, and for evaluating health benefits and clinicians' attitudes. Indeed, a recent survey showed that only about 50% of clinicians have experience with AVGs or virtual reality, with poor knowledge and lack of time for implementing them into practice reported as the main barriers to address [52].

Concerning the levels of PA that might induce positive behavioural changes, in the reviewed articles we did not find specific discussions and recommendations about PA levels other than WHO recommendations. Further studies are therefore required to facilitate the integration of new technologies for promoting and sustaining PA in childhood into real life as well as into clinical practice.

This review provides a summary of the most recent technological devices for promoting PA in children and adolescents, summarizing the available knowledge about their efficacy, and highlighting the main research gaps. Moreover, it provides insights into their usefulness in specific conditions (CRDs) and in specific contexts (the COVID-19 pandemic). Among limitations, due to differences in study populations (age, country) and methodologies (for the assessment of PA levels), it was difficult to provide scientific evidence about which of the new technologies are most effective to reach international recommendations for PA and what level of PA might induce positive behavioural changes in healthy children and in those with CRDs. More in general, our narrative review did not follow a specific protocol as with systematic reviews. In particular, we did not follow predefined protocols for the literature search and the critical appraisal of the studies quality. Therefore, this may have limited the strength of the scientific evidence.

5. Conclusions

The current review provides an overview of the most recent technological devices that can be used in childhood for promoting PA. A critical reappraisal of published studies highlighted the need of additional randomized controlled trials, along with longitudinal evaluation, which are essential for achieving more clear and robust evidence.

In conclusion, new technologies such as web/mobile apps and AVGs can be innovative and targeted health interventions to increase PA levels in healthy children and in those with CRDs. These emergent tools are also promising for counteracting the declining trend in PA observed during the current COVID-19 pandemic, and may be useful for improving short-term psychological wellbeing in healthy children. In particular, innovative technologies may help to develop and improve interventions aimed at inducing positive behavioural changes related to PA, by enhancing the interaction between the health system, school and family. Moreover, the integration of new technologies for promoting and sustaining PA into clinical practice requires interdisciplinary collaboration to cover all aspects contributing to establish frequency, duration, and type of targeted PA programs in children. Further research is warranted to provide more robust results about the efficacy of new technologies in reaching international recommendations for PA in childhood.

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