Journal of Public Health (2023) 31:2103–2114
https://doi.org/10.1007/s10389-022-01763-7

ORIGINAL ARTICLE

# Applying the COM-B model to understand wearable activity tracker use in children and adolescents

Amy V. Creaser[1,2] · Stacy A. Clemes[1,3] · Daniel D. Bingham[2] · Silvia Costa[1]

Received: 28 July 2022 / Accepted: 7 October 2022 / Published online: 27 October 2022


## Abstract

**Aim** Wearable activity trackers (wearables) are increasingly popular intervention tools for increasing child and adolescent physical activity (PA) levels. However, the large-scale habitual use of wearables in children and adolescents is unknown. This study investigated the prevalence of wearable use in children and adolescents, and what factors impact their use.

**Subjects and methods** This study utilised a cross-sectional survey and the 'Capability, Opportunity, Motivation and Behaviour' (COM-B) model was applied to explore what child/adolescent and parental characteristics impact wearable use. Parents/guardians of 5- to 17-year-olds were invited to complete the survey. The survey was open internationally, and consisted of between 19 and 23 questions, depending on child/adolescent wearable use. Multinomial logistic regression analyses were conducted to explore variables impacting wearable use, in children (5 to 9 years) and adolescents (10 to 17 years).

**Results** The survey was completed by 652 parents, representing 831 children/adolescents. Most children/adolescents had never used a wearable ($n = 429$; 51.6%), and 252 (30.3%) and 150 (18.1%) currently or had previously used a wearable, respectively. Child age and sex, capability, opportunity and motivation for PA were associated with wearable use, and differences were present between child (5 to 9 years) and adolescent (10 to 17 years) wearable use.

**Conclusions** This study offers a novel contribution to the understanding of child and adolescent habitual wearable use, and what impacts wearable use in these age groups.

**Keywords** Child · Adolescent · Wearable activity trackers · COM-B model · TDF

## Background

Physical activity (PA) during childhood and adolescence is associated with health benefits such as lower risks of obesity and improved well-being (da Silva et al. 2019; Mark and Janssen 2011; Poitras et al. 2016; Talarico and Janssen 2018). However, current estimates suggest that less than half of children and adolescents are participating in the recommended 60 minutes of moderate-to-vigorous-intensity PA (MVPA) on average every day (Colley et al. 2011; Cooper et al. 2015). On the other hand, technology use (e.g. mobile phones, social media) in children and adolescents is more prevalent (Ofcom 2019). Consequently, there is growing interest in how technology can be used to promote child and adolescent health and well-being, such as PA (Rose et al. 2017).

Technology-based interventions, such as apps, pedometers, and motivational text messaging, can increase step counts (Langarizadeh et al. 2021; Lau et al. 2011), time spent in light- and moderate- PA (Lau et al. 2011) and total PA levels in children and adolescents (He et al. 2021). Since 2016, there has been growing interest in the use of wearable activity trackers (wearables) as intervention tools for PA behaviour change (Creaser et al. 2021; Ridgers et al. 2016). Wearables (e.g. Fitbit, Garmin) are commercially available devices that track momentary PA to provide incremental and long-term feedback, going beyond a traditional 'step-only' display (Creaser et al. 2021; Ridgers et al. 2016). Although wearable use in intervention studies is of interest,

✉ Amy V. Creaser
amy.creaser@bthft.nhs.uk

1 School of Sport, Exercise, and Health Sciences, Loughborough University, Loughborough LE11 3TU, UK

2 Bradford Institute for Health Research, Bradford Teaching Hospitals Foundation Trust, Bradford BD9 6RJ, UK

3 National Institute for Health Research (NIHR) Leicester Biomedical Research Centre, University Hospitals of Leicester NHS Trust, University of Leicester, Leicester LE5 4PW, UK

the habitual use of wearables in children and adolescents is unknown. Understanding the large-scale use will provide initial insights into their ability to combat population-level health concerns, such as child inactivity and obesity (Armstrong et al. 2020; Hales et al. 2019).

Previous research has explored the habitual use of wearables in adult populations and found that individual characteristics, such as body mass index and how the wearable was received (e.g. as a gift) influenced whether adults used a wearable (Friel and Garber 2020). What impacts wearable use in children and adolescents is currently unknown. This study applied the Capability, Opportunity, Motivation and Behaviour (COM-B) model (Michie et al. 2011), as well as demographic data (e.g. age, sex, parental education), to explore factors impacting wearable use in children and adolescents. The COM-B model suggests that capability (physical or psychological), opportunity (physical or social) and motivation (automatic or reflective) interact with behaviour (e.g. PA), in a bi-directional manner (Michie et al. 2015). The COM-B model can be further refined into components outlined by the Theoretical Domains Framework (TDF) (Atkins et al. 2017). The TDF is a comprehensive framework consisting of 14 domains, derived from 33 psychological theories of behaviour change, which align with components of the COM-B model (Atkins et al. 2017). The COM-B model/TDF has previously been used to explore families' acceptance of wearables (Creaser et al. 2022), but its use in this study can provide key insights into whether child/adolescent, or their parents, capability, opportunity and motivation, and its sub-components (TDF), impacts habitual wearable use.

This study used a cross-sectional survey, based on the COM-B model and TDF, to explore the prevalence of wearable use, and what impacts wearable use, in 5- to 17-year-olds.

## Methods

### Design

This study utilised a cross-sectional survey to investigate the prevalence of wearable use, in 5- to 17-year-olds. The 'Capability, Opportunity, Motivation and Behaviour' (COM-B) model and 'Theoretical Domains Framework' (TDF) were applied to explore what child/adolescent and parental characteristics impact child and adolescent wearable use.

### Participants and procedure

This study received ethical approval from the Loughborough University Ethical Approvals (Human Participants) Sub-Committee (REF 2021-4326-3975). Parents and guardians of 5- to 17-year-old children were invited to complete an online survey. Parental report was required for all age groups, due to all age groups being under the age of 18 years. The survey was hosted by 'Online Surveys' (https://www.onlinesurveys.ac.uk/), and a convenience sample was used to recruit parents/guardians via advertisements on social media (e.g. authors' Twitter and Facebook profiles and parent forums). The survey was open internationally (and hence why a convenience sample was used), but only available in English. Parents/guardians were provided with information about the survey (e.g. aims, eligibility, right to withdraw, how their personal information will be stored and processed) via an information sheet within the online survey platform, and parent/guardian eligibility was assessed ('Are you a parent/guardian (you must be 18 years or older to complete this survey) of a child, aged between 5 and 17 years?'). Parents/guardians provided consent by selecting a check box to confirm they agree with the information provided and were happy to participate in the study. Respondents completed one survey per child, with the option of completing a survey for up to three children. Respondents were entered into a prize draw to win one of three £20 online shopping vouchers. The survey took approximately 20 minutes to complete and was available between May and August 2021 (68 days).

### Measures

Before the survey began, respondents were provided with the following statement, to provide clarity on the term 'wearable activity tracker': '*This survey uses the term "wearable activity/fitness tracker(s)". This refers to devices that can be worn on the body (most commonly on the wrist like a watch) that measures how much physical activity you have done. This may include how many steps, or miles you have walked. Some wearable activity/fitness trackers also measure how quickly your heart is beating, how much you sleep, and may remind you to be active. They include devices such as Fitbit, Garmin, Misfit, Apple iWatch, or other similar devices'*. This was paraphrased (to ensure it was lay-friendly) from a previous systematic review's definition of wearables (Creaser et al. 2021).

Supplementary Table S1 displays the survey questions and response options. The survey consisted of between 19 and 23 items (including demographic questions), depending on whether the child; (1) currently ($n = 21$), (2) previously (but no longer) ($n = 23$), or (3) had never ($n = 19$) used a wearable. Questions were developed based on previous research using the same theoretical underpinnings (TDF, COM-B model) (Creaser et al. 2022; Eddy et al. 2021), and were derived based on the recommendations and terminology outlined by Michie et al. (2015) (e.g. using examples from the 'COM-B self-evaluation questionnaire'; Michie et al. 2015)

The face validity of the survey items was evaluated by a multi-disciplinary team ($n = 5$), who provided critical insights into the appropriateness of the items, compared to the definitions outlined by Michie et al. (2015). This is a previously used method for assessing the face validity of surveys using the COM-B model as a theoretical underpinning (Bennett et al. 2022).

### Data cleaning

Consistent with previous research (Parsons et al. 2022; Shin and Hickey 2021), responses for 'strongly agree' and 'agree', and 'strongly disagree' and 'disagree' were combined, alongside 'neither agree nor disagree' (depending on the direction of question). Ages 15, 16 and 17 years were re-categorised into the age group '15 to -17 years', due to a smaller number of responses in these age groups. Other responses were also re-categorised (e.g. parent's education, correct or incorrect definition of MVPA, parent's understanding of PA guidelines; <60 minutes or ≥60 minutes). A lack of response variation (at least one response contributed to <10% of overall responses) remained for 'child ethnicity' (demographics), 'child physical abilities to be active', 'child technology skills to use a wearable' (physical skills), 'child access to Wi-Fi' and 'child access to a smart device' (environmental context and resources), and they were unable to be included in the regression analyses (see 'data analyses' section).

### Data analyses

The frequency (n, %) of responses are presented, including the prevalence of child and adolescent wearable use. Two enter multinomial logistic regression analyses were conducted to explore the impact of child/adolescent and parent demographics, capability, opportunity and motivation variables on child and adolescent wearable use (currently, previously or never used). Analyses were stratified by age group: children (5- to 9 years) and adolescents (10 to 17 years), based on the World Health Organization's definitions (World Health Organization 2021). The analyses were stratified in this way to detect any potential differences based on age groups, given previous research has reported differences in technology use between younger and older children (e.g. smartphones) (Spina et al. 2021). An enter model was used based on the theoretical underpinnings of the COM-B model, in that behaviour is a result of all its components in combination (capability, opportunity and motivation) (Michie et al. 2015). The number of surveys each parent/guardian completed (one (0) or multiple (1)) were included in the regression models as a co-variate to account for any biases in responses. The reference group for both regression analyses was 'never used a wearable'. The regression analyses were conducted using Statistical Package for the Social Sciences (SPSS, IBM, Chicago, U.S.A) version 25, and the significance level set at $p \leq 0.05$.

## Results

A total of 652 parents/guardians completed the survey, with 160 completing a survey for more than one child ($n = 19$ for three children). This resulted in responses for 831 children.

### Respondent demographics

Parent and child demographics are presented in Table 1. Respondents lived across 21 countries, with most from the United Kingdom ($n = 525$; 80.5%), followed by the United States of America ($n = 50$; 7.7%), Australia ($n = 27$; 4.1%), Canada ($n = 12$; 2%) and New Zealand ($n$=4; 0.6%). Other respondents were from countries in Europe ($n = 22$; 3.4%), Asia ($n$=7; 1.1%), Africa ($n = 2$; 0.3%) and North America ($n = 1$; 0.2%). Two did not specify their country of residence. Most respondents were mothers ($n = 599$; 91.9%) (followed by fathers ($n = 42$; 6.4%) and guardians ($n = 11$; 1.7%)), had an undergraduate degree or above ($n = 468$; 72%) and currently used a wearable ($n = 380$; 58.3%). Children had an average age of 9.5 years (SD: 3.37), and most children were white ethnicity ($n = 725$; 87.2%), and 51.9% were males ($n = 431$).

### Prevalence of wearable use

Table 2 displays survey responses for child and adolescent wearable use and non-use. Most children and adolescents had never used a wearable ($n = 429$; 51.6%), and 252 (30.3%) and 150 (18.1%) currently or had previously used a wearable, respectively. Most children/adolescents used a wearable multiple times a day, and for either 1 to 2 years (currently 26.6–32%) or 1 to 5 months (previously 38.1–41.5%). Most children and adolescents used a wearable to track or monitor their PA levels (currently 64.5–69.5%, previously 37.7–53.6%) or because of interest in new technology (currently 33.6–35.5%, previously 53.6–58.5%). Differences in using wearables for weight loss were apparent between those who currently use a wearable (3.6%) and had previously used a wearable (42.7%), with slightly more adolescents (45.4%) previously using a wearable to aid weight loss than children (37.7%). The most reported reason for discontinuing use was loss of interest, for both children and adolescents (43.4–60.8%), and the most common reasons for children and adolescents having never used a wearable was expressing no interest (29–49.3%) and wearables being too expensive (24.7–33%). More parents of children reported their child did not use a wearable as they did not need to increase their PA levels (28.7%) than adolescents (13.3%).

**Table 1** Respondent demographics, n (%)

| | Currently uses ($n = 252$) | Previously used ($n = 150$) | Never used ($n = 429$) | Total ($n$=831) |
|---|---|---|---|---|
| Child's gender | | | | |
| Male | 119 (47.2%) | 84 (56%) | 228 (53.1%) | 431 (51.9%) |
| Female | 132 (52.4%) | 65 (43.3%) | 200 (46.6%) | 397 (47.8%) |
| Other | 1 (0.4%) | 1 (0.7%) | 1 (0.2%) | 3 (0.3%) |
| Child's age | | | | |
| 5 years | 8 (3.2%) | 4 (2.7%) | 88 (20.5%) | 100 (12%) |
| 6 years | 25 (9.9%) | 10 (6.7%) | 66 (15.4%) | 101 (12.2%) |
| 7 years | 23 (9.1%) | 8 (5.3%) | 48 (11.2%) | 79 (9.5%) |
| 8 years | 34 (13.5%) | 16 (10.7%) | 42 (9.8%) | 92 (11.1%) |
| 9 years | 38 (15.1%) | 35 (10%) | 35 (8.2%) | 88 (10.6%) |
| 10 years | 36 (14.3%) | 16 (10.7%) | 19 (4.4%) | 71 (8.5%) |
| 11 years | 21 (8.3%) | 19 (12.7%) | 25 (5.8%) | 65 (7.8%) |
| 12 years | 18 (7.1%) | 17 (11.3%) | 21 (4.9%) | 56 (6.7%) |
| 13 years | 16 (6.3%) | 12 (8%) | 28 (6.8%) | 56 (6.7%) |
| 14 years | 9 (3.6%) | 11 (7.3%) | 19 (4.4%) | 39 (4.7%) |
| 15 years | 9 (3.6%) | 10 (6.7%) | 14 (3.3%) | 33 (4%) |
| 16 years | 9 (3.6%) | 5 (3.3%) | 14 (3.3%) | 28 (3.4%) |
| 17 years | 6 (2.4%) | 7 (4.7%) | 10 (2.3%) | 23 (2.8%) |
| Child's ethnicity | | | | |
| White | 235 (93.3%) | 138 (92%) | 352 (82.1%) | 725 (87.2%) |
| Asian | 5 (2%) | 0 | 19 (4.4%) | 24 (2.9%) |
| Hispanic | 4 (1.6%) | 3 (2%) | 6 (1.4%) | 13 (1.6%) |
| Middle Eastern | 1 (0.4%) | 2 (1.3%) | 4 (0.9%) | 7 (0.8%) |
| Black | 1 (0.4%) | 0 | 3 (0.7%) | 4 (0.5%) |
| American Indian | 0 | 0 | 1 (0.2%) | 1 (0.1%) |
| Mixed | 6 (2.4%) | 7 (4.6%) | 42 (9.8%) | 55 (6.6%) |
| Rather not say | 0 | 0 | 2 (0.5%) | 2 (0.2%) |
| Parent highest educational qualification[a] | | | | |
| No schooling | 1 (0.4%) | 1 (0.7%) | 6 (1.4%) | Total $n = 652$ |
| Primary Education | 2 (0.8%) | 0 | 5 (1.2%) | 6 (0.9%) |
| Secondary Education | 23 (9.1%) | 13 (8.7%) | 34 (7.9%) | 6 (0.9%) |
| Advanced Subsidiary Level | 7 (2.8%) | 7 (4.7%) | 22 (5.1%) | 49 (7.5%) |
| Advanced Level | 44 (17.5%) | 24 (16%) | 49 (11.4%) | 29 (4.4%) |
| Undergraduate Degree | 71 (28.2%) | 41 (27.3%) | 143 (33.3%) | 93 (14.3%) |
| Professional Degree | 39 (15.5%) | 28 (18.7%) | 83 (19.3%) | 213 (31.7%) |
| Master's Degree | 43 (17.1%) | 18 (12%) | 49 (11.4%) | 84 (12.9%) |
| Doctoral Degree | 21 (8.3%) | 18 (12%) | 38 (8.9%) | 117 (17.9%) |
| Unable to classify | 1 (0.4%) | 0 | 0 | 54 (8.3%) |
| | | | | 1 (0.2%) |

[a] Total number of parent respondents $n = 652$, but responses have also been sub-divided based on child wearable use ($n = 252$, 150 and 429)

## Variables impacting wearable use – regression analyses

Supplementary Table S2 displays the survey responses for parent and child capability, opportunity and motivation.

**Children (5 to 9 years)** Table 3 displays the odds ratio tests for child and parent demographics, capability, opportunity and motivation for PA impact on child (5 to 9 years) wearable use. The multinomial regression analysis found that including child and parent demographics, capability, opportunity and motivation data into the model provided a better fit for wearable use than the intercept only model ($\chi 2\ (36) = 209.8, p <$ 0.001). Children aged 5 years (demographics) were less likely to currently use a wearable, than have never used a wearable (compared to their reference groups; Table 3). Children who understood what a wearable is (psychological capability) and children who do not enjoy being active (automatic motivation) were more likely to currently use a wearable than have never used a wearable. Children with parents who currently use a wearable (social opportunity) were more likely to currently and have previously used a wearable (compared to children with parents who have never used a wearable), and children with no or little understanding of the term 'MVPA' (psychological capability) were less likely to have previously used a wearable than have never used a wearable.

**Table 2** Survey responses for wearable use and non-use, n (%)

| | Children (5 to 9 years) | | | Adolescents (10 to 17 years) | | |
|---|---|---|---|---|---|---|
| | Currently uses ($n$ = 128) | Previously used ($n$ = 53) | Never used ($n$=279) | Currently uses ($n$ = 124) | Previously used ($n$ = 97) | Never used ($n$=150) |
| Frequency of use | | | | | | |
| Multiple times a day | 55 (43%) | 25 (47.2%) | n/a | 66 (53.2%) | 37 (38.1%) | n/a |
| At least once a day | 36 (28.1%) | 9 (17%) | | 31 (25%) | 36 (37.1%) | |
| At least once a week | 26 (20.3%) | 10 (18.9%) | | 21 (16.9%) | 18 (18.6%) | |
| At least once a month | 10 (7.8%) | 4 (7.5%) | | 3 (2.4%) | 0 | |
| At least once a year | 1 (0.8%) | 3 (5.7%) | | 3 (2.4%) | 1 (1%) | |
| Less than once a year | 0 | 2 (3.8%) | | 0 | 3 (3.1%) | |
| Unsure | 0 | 0 | | 0 | 2 (2.1%) | |
| Duration of use | | | | | | |
| <1 month | 9 (7%) | 20 (37.7%) | n/a | 6 (4.8%) | 13 (13.4%) | n/a |
| 1–5 months | 36 (28.1%) | 22 (41.5%) | | 27 (21.8%) | 37 (38.1%) | |
| 6–11 months | 30 (23.4%) | 4 (7.5%) | | 30 (24.2%) | 22 (22.7%) | |
| 1 year – 2 years | 41 (32%) | 6 (11.3%) | | 33 (26.6%) | 20 (20.6%) | |
| >2 years | 12 (9.4%) | 1 (1.9%) | | 28 (22.6%) | 4 (4.1%) | |
| Unsure | 0 | 0 | | 0 | 1 (1%) | |
| Stopped using | | | | | | |
| <1 month ago | n/a | 4 (7.5%) | n/a | n/a | 5 (5.2%) | n/a |
| 1-5 months ago | | 24 (45.3%) | | | 23 (23.7%) | |
| 6-11 months ago | | 14 (26.4%) | | | 32 (33%) | |
| 1 year – 2 years ago | | 10 (18.9%) | | | 26 (26.8%) | |
| >2 years ago | | 1 (1.9%) | | | 11 (11.3%) | |
| Unsure | | 0 | | | 0 | |
| Reason for use[a] | | | | | | |
| Interest in new technology | 43 (33.6%) | 31 (58.5%) | n/a | 44 (35.5%) | 52 (53.6%) | n/a |
| Track/monitor PA | 89 (69.5%) | 20 (37.7%) | | 80 (64.5%) | 57 (58.8%) | |
| Increase PA | 24 (18.8%) | 8 (15.1%) | | 28 (22.6%) | 16 (16.5%) | |
| Track health unrelated to PA | 25 (19.5%) | 5 (9.4%) | | 29 (23.4%) | 18 (18.6%) | |
| Aid weight loss | 0 | 20 (37.7%) | | 9 (7.3%) | 44 (45.4%) | |
| Peer(s) uses a wearable(s) | 43 (33.6%) | 12 (22.6%) | | 39 (31.5%) | 27 (27.8%) | |
| Fashionable | 35 (27.3%) | 0 | | 23 (18.5%) | 2 (2.1%) | |
| Unsure | 0 | 1 (1.9%) | | 2 (1.6%) | 1 (1%) | |
| *Other:* | | | | | | |
| Used as a watch | 8 (6.3%) | 0 | | 3 (2.4%) | 2 (2.1%) | |
| Gift | 2 (1.6%) | 0 | | 0 | 0 | |
| Parent(s) uses a wearable(s) | 3 (2.3%) | 2 (3.8%) | | 0 | 0 | |
| Way of contact (text, calls) | 3 (2.3%) | 1 (1.9%) | | 3 (2.4%) | 0 | |
| Location/GPS | 2 (1.6%) | 1 (1.9%) | | 1 (0.8%) | 0 | |
| Study/Research project | 0 | 2 (3.8%) | | 0 | 0 | |
| Other[b] | 0 | 1 (1.9%) | | 0 | 0 | |

**Adolescents (10 to 17 years)** Table 4 displays the odds ratio tests for adolescent and parent demographics, capability, opportunity and motivation for PA impact on adolescent (10 to 17 years) wearable use. The multinomial regression analysis found that including adolescent and parent demographics, capability, opportunity and motivation data into the model provided a better fit for wearable use than the intercept only model ($\chi 2$ (38) = 94.79, $p < 0.001$). Male adolescents were less likely than females, and 10-year-olds were more likely than 15- to 17-year-old adolescents (demographics), to currently use a wearable. Adolescents with some understanding of the term 'MVPA' and who were active without thinking about it (both psychological capability) were less likely to currently use a wearable (compared to their reference groups; Table 4). Adolescents with a parent who currently uses or has previously used a wearable (social opportunity) were more likely to both currently use or have previously used a wearable.

## Discussion

This is the first study to use parental report to investigate the use of wearables and what impacts their use, using the COM-B model (Michie et al. 2011) and TDF (Atkins et al. 2017), in 5- to 17-year-olds. Child/adolescent

**Table 2** (continued)

| | Children (5 to 9 years) | | | Adolescents (10 to 17 years) | | |
|---|---|---|---|---|---|---|
| | Currently uses ($n$ = 128) | Previously used ($n$ = 53) | Never used ($n$=279) | Currently uses ($n$ = 124) | Previously used ($n$ = 97) | Never used ($n$=150) |
| Reason for stopping using[a] | | | | | | |
| Lost interest | n/a | 30 (43.4%) | n/a | n/a | 59 (60.8%) | n/a |
| Device broke | | 7 (13.2%) | | | 18 (18.6%) | |
| Lost the device | | 5 (9.4%) | | | 8 (8.2%) | |
| Did not accurately track PA | | 2 (3.8%) | | | 2 (2.1%) | |
| Did not increase PA | | 0 | | | 2 (2.1%) | |
| Did not aid weight loss | | 0 | | | 0 | |
| Did not enjoy | | 4 (7.5%) | | | 3 (3.1%) | |
| Unfashionable | | 0 | | | 4 (4.1%) | |
| Peers stopped using | | 0 | | | 7 (7.2%) | |
| Unsure | | 0 | | | 6 (6.2%) | |
| *Other:* | | | | | | |
| End of study/challenge | | 2 (3.8%) | | | 1 (1%) | |
| Unable to wear at school | | 3 (5.7%) | | | 2 (2.1%) | |
| Technology issues/burden | | 2 (3.8%) | | | 5 (5.2%) | |
| Discomfort/irritation | | 5 (9.4%) | | | 1 (1%) | |
| Negative health outcomes | | 1 (1.9%) | | | 2 (2.1%) | |
| Other[c] | | 2 (3.8%) | | | 4 (4.1%) | |
| Reason for not using[a] | | | | | | |
| Too expensive | n/a | n/a | 82 (33%) | n/a | n/a | 37 (24.7%) |
| No interest in using | | | 81 (29%) | | | 74 (49.3%) |
| Uses another way to track PA | | | 0 | | | 13 (8.7%) |
| Unfashionable | | | 2 (0.7%) | | | 3 (2%) |
| Would not enjoy | | | 25 (9%) | | | 13 (8.7%) |
| Does not need to increase PA | | | 80 (28.7%) | | | 20 (13.3%) |
| Does not know what a wearable is Unsure | | | 52 (18.6%) | | | 6 (4%) |
| | | | 12 (4.3%) | | | 10 (6.7%) |
| *Other:* | | | | | | |
| Too young | | | 34 (12.2%) | | | 1 (0.7%) |
| Not a good way to increase PA | | | 7 (2.5%) | | | 0 |
| Concerns over negative outcomes | | | 8 (2.9%) | | | 7 (4.7%) |
| Limiting technology use | | | 4 (1.4%) | | | 0 |
| Considered, but not yet purchased | | | 5 (1.8%) | | | 3 (2%) |
| Never considered | | | 3 (1.1%) | | | 2 (1.3%) |
| Unable to wear/use at school | | | 3 (1.1%) | | | 2 (1.3%) |
| Other[d] | | | 10 (3.6%) | | | 11 (7.3%) |

[a]Respondents could select more than one answer. [b] Other reasons included required to by sports coach, charity challenges. [c] Other reasons included unable to wear for sport (considered jewellery), 'obsession' with sleep tracking, no parental controls. [d] Other reasons included fears wearables can reduce children's ability to be a 'child', no need for their child to use one (but did not specify why)

demographics, capability, opportunity and motivation for PA influenced child and adolescent wearable use. Differences were present between children (5 to 9 years) and adolescent (10 to 17 years) wearable use.

## Wearable use

Children and adolescents most commonly used wearables to track or monitor their PA levels (37.7–69.5%). Children and parents often underestimate their own/their child's PA levels, and it is suggested that increasing awareness of PA levels may encourage behaviour change (Corder et al. 2010). However, despite the high prevalence of physical inactivity in children and adolescents (Colley et al. 2011; Cooper et al. 2015), fewer children and adolescents used a wearable to increase their PA levels (15.1–22.6%). In particular, more parents of children (5 to 9 years), than adolescents (10 to 17 years), reported their child did not need to increase their PA levels. A previous systematic review found that PA levels decline by an average of 3.4% to 5.3% per year from the age of 3 years to 16 years (Farooq et al. 2020), suggesting that using tools to increase PA may occur later in childhood/adolescence. As well as monitoring PA levels, wearables were used due to interest in new technology;

**Table 3** Odds ratios for COM-B variables influence on child (5 to 9 years) wearable use (currently, previously, never)

| | Child currently uses | | | | Child previously used | | | |
|---|---|---|---|---|---|---|---|---|
| | *b* (SE) | OR (95% CI) | Wald $\chi 2$ | *p* | *b* (SE) | OR (95% CI) | Wald $\chi 2$ | *p* |
| Demographics | | | | | | | | |
| Parent's education | | | | | | | | |
| <Undergraduate degree | –0.16 (0.36) | 0.85 (0.42–1.71) | 0.21 | 0.65 | 0.37 (0.44) | 1.45 (0.61–3.45) | 0.72 | 0.40 |
| Undergraduate degree | -0.45 (0.34) | 0.64 (0.32–1.25) | 1.73 | 0.19 | –0.05 (0.45) | 0.95 (0.40–2.28) | 0.01 | 0.92 |
| >Undergraduate degree | ref | ref | ref | ref | ref | ref | ref | ref |
| Child's gender | | | | | | | | |
| Male | –0.42 (0.29) | 0.66 (0.38–1.15) | 2.17 | 0.14 | –0.36 (0.36) | 0.70 (0.35–1.40) | 1.02 | 0.31 |
| Female | ref | ref | ref | ref | ref | ref | ref | ref |
| Child's age | | | | | | | | |
| 5 years | –1.13 (0.57) | 0.32 (0.11–0.99) | 3.88 | **0.05** | –0.53 (0.72) | 0.59 (0.14–2.40) | 0.55 | 0.46 |
| 6–years | –0.40 (0.44) | 0.67 (0.29–1.57) | 0.86 | 0.35 | –0.14 (0.56) | 0.87 (0.29–2.60) | 0.06 | 0.81 |
| 7–years | 0.04 (0.44) | 1.05 (0.44–2.46) | 0.01 | 0.92 | –0.07 (0.56) | 0.93 (0.31–2.81) | 0.02 | 0.90 |
| 8–years | 0.32 (0.41) | 1.38 (0.62–3.09) | 0.61 | 0.44 | 0.61 (0.50) | 1.84 (0.69–4.88) | 1.50 | 0.22 |
| 9–years | ref | ref | ref | ref | ref | ref | ref | ref |
| Capability | | | | | | | | |
| Parent's definition of MVPA | | | | | | | | |
| Correct | –0.30 (0.30) | 0.74 (0.41–1.34) | 0.98 | 0.32 | –0.08 (0.38) | 0.93 (0.44–1.94) | 0.04 | 0.84 |
| Incorrect | ref | ref | ref | ref | ref | ref | ref | ref |
| Parent's understanding of PA guidelines (minutes of MVPA) | | | | | | | | |
| <60 mins | –0.54 (0.29) | 0.58 (0.33–1.03) | 3.52 | 0.06 | –0.15 (0.36) | 0.86 (0.43–1.75) | 0.17 | 0.69 |
| ≥60–mins | ref | ref | ref | ref | ref | ref | ref | ref |
| Child's MVPA understanding | | | | | | | | |
| No/little | –0.55 (0.48) | 0.58 (0.22–1.49) | 1.29 | 0.26 | –1.17 (0.59) | 0.31 (0.10–0.98) | 3.96 | **0.05** |
| Some | –0.31 (0.44) | 0.73 (0.31–1.73) | 0.51 | 0.48 | –0.76 (0.52) | 0.47 (0.17–1.29) | 2.15 | 0.14 |
| A lot | ref | ref | ref | ref | ref | ref | ref | ref |
| Child does PA without thinking | | | | | | | | |
| Agree | –0.81 (0.50) | 0.48 (0.17–1.19) | 2.62 | 0.11 | 0.08 (0.63) | 1.08 (0.32–3.69) | 0.02 | 0.90 |
| Neither or disagree | ref | ref | ref | ref | ref | ref | ref | ref |
| Child understands wearable | | | | | | | | |
| Agree | 1.48 (0.49) | 4.37 (1.68–11.39) | 9.11 | **0.003** | 0.88 (0.68) | 2.40 (0.63–9.12) | 1.65 | 0.20 |
| Neither or disagree | ref | ref | ref | ref | ref | ref | ref | ref |
| Opportunity | | | | | | | | |
| Parent's wearable use | | | | | | | | |
| Currently | 2.23 (0.50) | 9.31 (3.53–24.58) | 20.30 | **0.001** | 1.33 (0.61) | 3.76 (1.14–12.44) | 4.72 | **0.03** |
| Previously | 0.55 (0.60) | 1.73 (0.53–5.59) | 0.83 | 0.36 | 0.88 (0.69) | 2.42 (0.63–9.31) | 1.65 | 0.20 |
| Never | ref | ref | ref | ref | ref | ref | ref | ref |
| Motivation | | | | | | | | |
| Child does not enjoy PA | | | | | | | | |
| Agree | 2.07 (0.49) | 7.94 (3.02–20.87) | 17.65 | **0.001** | 0.82 (0.50) | 2.27 (0.85–6.07) | 2.64 | 0.10 |
| Neither or disagree | ref | ref | ref | ref | ref | ref | ref | ref |
| Child is a physically active person | | | | | | | | |
| Agree | –0.36 (0.64) | 0.70 (0.20–2.47) | 0.31 | 0.70 | –0.77 (0.74) | 0.47 (0.11–1.98) | 1.08 | 0.30 |
| Neither or disagree | ref | ref | ref | ref | ref | ref | ref | ref |

Ref= child has never used a wearable

Bold $p \leq 0.05$

however, discontinuation of use and disuse were reportedly due to loss of or no interest in using a wearable. Interest in technology has also been reported as a key reason for adult wearable use (Friel and Garber 2020). Thus, for some children and adolescents, initial interests in using wearables may stem from their technology and ability to monitor behaviour, rather than change behaviour. Despite interest, research has found that wearables have a 'novelty effect', where children and adolescents reduce their wearable use at approximately 2–4 weeks (Creaser et al. 2021; Ridgers and Drehlich 2021).

**Table 4** Odds ratios for COM-B variables influence on adolescent (10 to 17 years) wearable use (currently, previously, never)

| | Adolescent currently uses | | | | Adolescent previously used | | | |
|---|---|---|---|---|---|---|---|---|
| | *b* (SE) | OR (95% CI) | Wald $\chi 2$ | *p* | *b* (SE) | OR (95% CI) | Wald $\chi 2$ | *p* |
| Demographics | | | | | | | | |
| Parent's education | | | | | | | | |
| <Undergraduate | 0.10 (0.36) | 0.46 (0.23–0.920 | 0.08 | 0.78 | –0.12 (0.37) | 0.89 (0.43–1.85) | 0.10 | 0.76 |
| degree | 0.47 (0.36) | 1.11 (0.55–2.24) | 1.76 | 0.19 | –0.47 (0.36) | 0.63 (0.31–1.26) | 1.74 | 0.19 |
| Undergraduate degree | ref | ref | ref | ref | ref | ref | ref | ref |
| >Undergraduate degree | | | | | | | | |
| Adolescent's gender | | | | | | | | |
| Male | –0.67 (0.29) | 0.51 (0.29–0.91) | 5.28 | **0.02** | 0.03 (0.30) | 1.03 (0.58–1.86) | 0.01 | 0.91 |
| Female | ref | ref | ref | ref | ref | ref | ref | ref |
| Adolescent's age | | | | | | | | |
| 10 years | 1.44 (0.49) | 4.22 (1.62–10.96) | 8.72 | **0.003** | 0.19 (0.52) | 1.20 (0.44–3.32) | 0.13 | 0.72 |
| 11–years | 0.59 (0.49) | 1.81 (0.70–4.69) | 1.47 | 0.23 | 0.25 (0.48) | 1.28 (0.50–3.26) | 0.27 | 0.61 |
| 12 years | 0.52 (0.50) | 1.68 (0.63–4.50) | 1.06 | 0.30 | 0.36 (0.49) | 1.44 (0.55–3.77) | 0.54 | 0.46 |
| 13–years | –0.20 (0.47) | 0.82 (0.32–2.08) | 0.17 | 0.68 | –0.88 (0.51) | 0.41 (0.15–1.12) | 3.05 | 0.08 |
| 14–years | –0.25 (0.55) | 0.78 (0.27–2.28) | 0.20 | 0.65 | –0.31 (0.52) | 0.73 (0.26–2.02) | 0.37 | 0.55 |
| 15–17–years | ref | ref | ref | ref | ref | ref | ref | ref |
| Capability | | | | | | | | |
| Parent's definition of MVPA | | | | | | | | |
| Correct | 0.36 (0.31) | 1.43 (0.77–2.65) | 1.31 | 0.25 | 0.16 (0.32) | 1.17 (0.63–2.19) | 0.25 | 0.62 |
| Incorrect | ref | ref | ref | ref | ref | ref | ref | ref |
| Parent's understanding of PA guidelines (minutes of MVPA) | | | | | | | | |
| <60–mins | –0.25 (0.29) | 0.78 (0.44–1.37) | 0.75 | 0.39 | –0.33 (0.29) | 0.72 (0.41–1.29) | 1.22 | 0.27 |
| ≥60–mins | ref | ref | ref | ref | ref | ref | ref | ref |
| Adolescent's MVPA understanding | | | | | | | | |
| No/little | –0.53 (0.56) | 0.59 (0.20–1.79) | 0.87 | 0.35 | –0.30 (0.58) | 0.74 (0.24–2.32) | 0.26 | 0.61 |
| Some | –0.69 (0.33) | 0.50 (0.26–0.96) | 4.28 | **0.04** | –0.23 (0.34) | 0.79 (0.40–1.56) | 0.46 | 0.50 |
| A lot | ref | ref | ref | ref | ref | ref | ref | ref |
| Adolescent does PA without thinking | | | | | | | | |
| Agree | –0.75 (0.37) | 0.47 (0.23–0.96) | 4.24 | **0.014** | –0.35 (0.38) | 0.71 (0.34–1.48) | 0.85 | 0.36 |
| Neither or disagree | ref | ref | ref | ref | ref | ref | ref | ref |
| Adolescent understands wearable | | | | | | | | |
| Agree | 2.16 (1.26) | 8.71 (0.73–103.66) | 2.93 | 0.09 | 1.81 (1.17) | 6.12 (0.62–60.66) | 2.40 | 0.12 |
| Neither or disagree | ref | ref | ref | ref | ref | ref | ref | ref |
| Opportunity | | | | | | | | |
| Parent's wearable use | | | | | | | | |
| Currently | 1.74 (0.36) | 5.69 (2.81–11.50) | 23.41 | **0.001** | 0.95 (0.35) | 2.58 (1.30–5.12) | 7.29 | **0.007** |
| Previously | 1.35 (0.48) | 3.84 (1.49–9.93) | 7.72 | **0.005** | 1.68 (0.44) | 5.38 (2.27–12.76) | 14.59 | **0.001** |
| Never | ref | ref | ref | ref | ref | ref | ref | ref |
| Motivation | | | | | | | | |
| Adolescent does not enjoy PA | | | | | | | | |
| Agree | 0.34 (0.36) | 1.40 (0.70–2.82) | 0.90 | 0.34 | 0.48 (0.37) | 1.61 (0.78–3.33) | 1.67 | 0.20 |
| Neither or disagree | ref | ref | ref | ref | ref | ref | ref | ref |
| Adolescent is a physically active person | | | | | | | | |
| Agree | 0.34 (0.44) | 1.41 (0.60–3.34) | 0.61 | 0.44 | –0.08 (0.45) | 0.92 (0.38–2.22) | 0.03 | 0.86 |
| Neither or disagree | ref | ref | ref | ref | ref | ref | ref | ref |

Ref= adolescent has never used a wearable

Bold $p \leq 0.05$

This study found that although most children and adolescents used the wearable multiple times a day, most children and adolescents who had previously used a wearable, used the wearable between 1- to 5 months, followed by less than 1 month, before discontinuing use. This may demonstrate a potential novelty effect and loss of interest when using

wearables. On the other hand, between 37.7% and 45.4% of children and adolescents, who had previously used a wearable, used the wearable for weight loss. This may reflect wearables use to achieve shorter term goals (weight loss) than longer term sustained goals, such as PA. Future research would benefit from exploring the initial interest of wearables further and consider how interest of using wearables can be maintained overtime in children and adolescents and differ dependent on the behaviour desired to be changed (weight loss vs increase PA). Another reason for non-use was the cost of wearables, and this must be investigated further to consider whether wearables may increase child health inequalities in PA levels (e.g. considering whether household income impacts wearable use).

## Demographics

Child and adolescent age were associated with wearable use. Children aged 5 years, compared to 9 years, were less likely to currently, than never, use a wearable, but adolescents aged 10 years, compared to 15 to 17 years, were more likely to currently, than never, use a wearable. More parents of children than adolescents reported their child was 'too young' to use a wearable (12.2% versus 0.7%), which may explain some of these findings. Most research using wearables as part of intervention or feasibility studies have targeted adolescents (10 to 19 years) versus children (e.g. <10 years, see systematic review by Creaser et al. 2021). The current study's findings provide some justification for exploring the use of wearables as intervention tools in older children or younger adolescents. Male adolescents (but no association was found in children), compared to females, were less likely to currently, than never, use a wearable. Typically, males are more active than females (Crespo et al. 2013; Ruiz et al. 2011; Verloigne et al. 2012), and this finding provides insights into the potential acceptability of using wearables for increasing girls' PA levels. Future research may wish to further explore these findings by investigating reasons behind child sex and age differences in wearable use.

## Capability

Most parents had good knowledge of the term MVPA and the recommended amount of MVPA children should achieve per day (≥60 minutes). Most parents also reported their child had some or a lot of understanding of the term MVPA, understood what a wearable is and had the technology skills to use a wearable. Nearly all children/adolescents had the physical abilities to be active and reportedly did PA without thinking about it. Therefore, this study's sample had high levels of capability to be active and use a wearable. Child and adolescent's knowledge of PA (MVPA) was associated with wearable use, with less understanding associated with less likelihood of currently or previously using a wearable. No other studies have explored the association between child/adolescent's understanding of PA and wearable use. Owing to the cross-sectional nature of this study, cause and effect cannot be determined, and it is unclear whether such knowledge was a result of using a wearable. However, previous research has found that wearables are limited in their ability to improve parent's understanding of child PA recommendations (Creaser et al. 2022), but it is unclear how this translates to child/adolescent knowledge and how these results may have been mediated by other socio-economic factors. Unsurprisingly, children who understood what a wearable was were more likely to currently use or have previously used a wearable, than have never used a wearable (but this was not found in adolescents). This may reflect that by simply understanding what a wearable is may be a key reason for wearable use in children, but not adolescents, and motivation for using a wearable may be more complex in adolescents. This study also found that adolescents who did PA without thinking about it were less likely to currently, than never, use a wearable. As adolescents in this sample were more likely to use wearables to monitor their PA levels, than increase their PA levels, adolescents who do not consciously think about being active may already be aware of their PA levels, and do not need to utilise a wearable to support this awareness. However, being a 'physically active person' did not predict wearable use in children or adolescents.

## Opportunity

Almost all children in this sample had the physical opportunities to use a wearable (access to Wi-Fi and a smart device), and over three-quarters of parent respondents either currently used or had previously used a wearable. Both children and adolescents with a parent who currently use or had previously used a wearable were more likely to currently use or have previously used a wearable. Previous research has similarly found that parental screen use is associated with child screen use, with parental attitudes towards screen use also having an impact (Lauricella et al. 2015). A recent study found that providing parents and children with a wearable can increase awareness of PA levels and promote PA via competition (Creaser et al. 2022), with another study finding wearables can prompt families to discuss health with one another (Sharaievska et al. 2019). Therefore, parent wearable use (current or previous) impacts child/adolescent wearable use, and this co-use of wearables may be beneficial, such as adopting healthier lifestyles (Creaser et al. 2022) and increasing conversations about health (Sharaievska et al. 2019). Thus, providing both parents and their children with wearables may be a useful intervention strategy in future work (Creaser et al. 2022).

### Motivation

Most parents reported their child was a physically active person and enjoyed being active. Children (but not adolescents) who did not enjoy being active were more likely to currently, than never, use a wearable. Qualitative research has found that children use wearables for fun (e.g. seeing a change in numbers) (Bopp and Vadeboncoueur 2021). Therefore, wearables may facilitate and sustain (the finding was only significant for children who currently use a wearable, than have previously used a wearable) the enjoyment of PA, in children who typically do not enjoy being active. However, whether children or adolescents were considered a 'physically active person' did not predict wearable use. This contrasts with surveys exploring adult wearable use, which have found that inactive adults (self-reported) are less likely to use a wearable or pedometer (Alley et al. 2016), and active adults are more likely to use a wearable (Friel and Garber 2020). Owing to the cross-sectional nature of the current study and having not measured child/adolescent PA level, it is unclear whether actual PA levels may impact initial wearable use in children and adolescents.

### Strengths and limitations

This is the first study to explore the large-scale use of wearables in children and adolescents and utilise theoretical frameworks to do so. This, particularly with the study's high response rate, offers insights into whether wearables are acceptable for large scale use to change PA behaviours. Some limitations of this study reflect the demographics of the parents and children who completed the survey. Most parents had an undergraduate degree or above, an understanding of child PA recommendations and currently or had previously used a wearable, and therefore may not be representative of the general population. Similarly, most children reportedly did PA without thinking about it, were considered an active person, enjoyed PA, and had the technology skills and environmental resources (Wi-Fi, smart devices) to use a wearable, and very few were older adolescents (e.g. 2.8% were 17-year-olds). Some of these characteristics may have been due to the convenience sampling and methods used to recruit parents/guardians (e.g social media; therefore children are likely to have access to Wi-Fi). Therefore, the sample is not representative of the general population, and other sampling methods should be considered in future research. The international nature of the sample had the potential to be a strength in this study, with similar surveys exploring wearable use (in adults) limited to American citizens (Friel and Garber 2020). However, 81% of the sample were from the United Kingdom and most children were of white ethnicity. Therefore, the worldwide prevalence of child and adolescent wearable use cannot be determined, nor the current findings generalised to less Westernised countries. Indeed, previous research has found differences in technology use (e.g. internet usage) between countries (Kardefelt-Winther et al. 2020). Furthermore, this study relied on parental report and children's opinions were not collected, due to ethical considerations (inability to monitor if parental consent was received before the child completed the survey). Previous research has highlighted the importance of considering children's, as well as parent's, opinions on wearable use (Creaser et al. 2022). Finally, a limitation of this study was its cross-sectional nature. Owing to this, this study relied on some parents recalling their child's use of a wearable that may have been more than two years ago (previously used), and cause and effect cannot be determined. Longitudinal studies are required to explore the causational relationship between components of the COM-B model and TDF and child and adolescent wearable use.

## Conclusions

This study is the first study to investigate the prevalence of wearable use in children and adolescents and provides insights into how parent and child demographics (child age and sex) capability (knowledge; memory, attention, and decision processes), opportunity (social influences) and motivation (emotion) impacts wearable use in children and adolescents. These findings offer initial and novel insights into wearables potential for combating public health concerns, such as child and adolescent physical inactivity levels. Researchers may wish to utilise this study's findings by considering how to embed wearables into future interventions, such as targeting older children or younger adolescents and females, and considering the role of the parent, including their own wearable use. Further research is needed to understand characteristics impacting the longitudinal use of wearables in children and adolescents, and characteristics impacting wearable's ability to change child and adolescent behaviour, such as PA levels.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s10389-022-01763-7.

**Authors' contributions** **Conceptualization,** A.V.C, S.A.C, D.D.B and S.C; **Methodology,** A.V.C, S.A.C, D.D.B and S.C; **Formal analysis,** A.V.C.; **Investigation,** A.V.C, S.A.C, D.D.B and S.C; **Writing – original draft preparation,** A.V.C; **Writing – review and editing,** A.V.C, S.A.C, D.D.B and S.C; **Supervision,** S.A.C, D.D.B and S.C.

**Funding** This study was funded as part of a Ph.D. studentship by the Born in Bradford study. The Born in Bradford study receives core infrastructure funding from the Wellcome Trust (WT101597MA) and the National Institute for Health Research (NIHR), under its NIHR ARC Yorkshire and Humber (NIHR200166) and Clinical Research Network (CRN) research delivery support. For this piece of work, funding from the Sport England's Local Delivery Pilot awarded Born in Bradford

funding for this Ph.D. studentship. S.A.C. is supported by the NIHR Leicester Biomedical Research Centre – Lifestyle theme. The views expressed in this publication are those of the authors and not necessarily those of the National Institute for Health Research or the Department of Health and Social Care.

**Data availability** Materials and dataset are available from the corresponding author upon request.

**Code availability** N/A

## Declarations

**Ethical approval** This study was approved by Loughborough University Ethical Approvals (Human Participants) Sub-Committee (REF: 2021-4326-3975).

**Consent to participate** Informed consent was obtained from each child's parent or guardian, who completed the study.

**Consent for publication** Participants provided informed consent for the data they provided to be anonymously disseminated in journals.

**Conflicts of interests** The authors declare that there are no conflicts of interest.



## References

Alley S, Schoeppe S, Guertler D, Jennings C, Duncan MJ, Vandelanotte C (2016) Interest and preferences for using advanced physical activity tracking devices: results of a national cross-sectional survey. BMJ Open 6(7):e011243. https://doi.org/10.1136/bmjopen-2016-011243

Armstrong S, Li JS, Skinner AC (2020) Flattening the (BMI) curve: timing of child obesity onset and cardiovascular risk. Pediatrics 146(2). https://doi.org/10.1542/peds.2020-1353

Atkins L, Francis J, Islam R, O'Connor D, Patey A, Ivers N, Foy R, Duncan EM, Colquhoun H, Grimshaw JM, Lawton R, Michie S (2017) A guide to using the theoretical domains framework of behaviour change to investigate implementation problems. Implement Sci 12(1):77. https://doi.org/10.1186/s13012-017-0605-9

Bennett RJ, Eikelboom RH, Sucher CM, Ferguson M, Saunders GH (2022) Barriers and facilitators to delivery of group audiological rehabilitation programs: a survey based on the COM-B model. Int J Audiol 61(2):130–139. https://doi.org/10.1080/14992027.2021.1928304

Bopp T, Vadeboncoueur JD (2021) It makes me want to take more steps: racially and economically marginalized youth experiences with and perceptions of Fitbit Zips® in a sport-based youth development program. J Sport Dev 9(2):54–67

Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS (2011) Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. Health Rep 22(1):15

Cooper AR, Goodman A, Page AS, Sherar LB, Esliger DW, van Sluijs EM, ..., Ekelund U (2015) Objectively measured physical activity and sedentary time in youth: the International children's accelerometry database (ICAD). Int J Behav Nutr Phys Act 12(1):1–10. https://doi.org/10.1186/s12966-015-0274-5

Corder K, van Sluijs EM, McMinn AM, Ekelund U, Cassidy A, Griffin SJ (2010) Perception versus reality: awareness of physical activity levels of British children. Am J Prev Med 38(1):1–8. https://doi.org/10.1016/j.amepre.2009.08.025

Creaser AV, Clemes SA, Costa S, Hall J, Ridgers ND, Barber SE, Bingham DD (2021) The acceptability, feasibility and effectiveness of wearable activity trackers for increasing physical activity in children and adolescents: a systematic review. Int J Environ Res Public Health 18(12):6211. https://doi.org/10.3390/ijerph18126211

Creaser AV, Hall J, Costa S, Bingham DD, Clemes SA (2022) Exploring families' acceptance of wearable activity trackers: a mixed-methods study. Int J Environ Res Public Health 19(6):3472. https://doi.org/10.3390/ijerph19063472

Crespo NC, Corder K, Marshall S, Norman GJ, Patrick K, Sallis JF, Elder JP (2013) An examination of multilevel factors that may explain gender differences in children's physical activity. J Phys Act Health 10(7):982–992. https://doi.org/10.1123/jpah.10.7.982

da Silva BGC, da Silva ICM, Ekelund U, Brage S, Ong KK, Rolfe EDL, …, Horta BL (2019) Associations of physical activity and sedentary time with body composition in Brazilian young adults. Sci Rep 9(1):1–10. https://doi.org/10.1038/s41598-019-41935-2

Eddy L, Hill LJ, Mon-Williams M, Preston N, Daly-Smith A, Medd G, Bingham DD (2021) Fundamental movement skills and their assessment in primary schools from the perspective of teachers. Meas Phys Educ Exerc Sci 25(3):236–249. https://doi.org/10.1080/1091367X.2021.1874955

Farooq A, Martin A, Janssen X, Wilson MG, Gibson AM, Hughes A, Reilly JJ (2020) Longitudinal changes in moderate to vigorous intensity physical activity in children and adolescents: a systematic review and meta analysis. Obes Rev 21(1):e12953. https://doi.org/10.1111/obr.12953

Friel CP, Garber CE (2020) Who uses wearable activity trackers and why? A comparison of former and current users in the United States. Am J Health Promot. https://doi.org/10.1123/jsep.2019-0170

Hales C, Carroll M, Fryar C, Ogden C (2019) Prevalence of obesity among adults and youth: United States, 2015-2016. NCHS Data Brief. 2017;(288): 1–8. Key findings from the NHANES study that overall prevalence of obesity is higher among non-Hispanic black and Hispanic adults than among non-Hispanic white and non-Hispanic Asian adults

He Z, Wu H, Yu F, Fu J, Sun S, Huang T et al (2021) Effects of smartphone-based interventions on physical activity in children and adolescents: systematic review and meta-analysis. JMIR mHealth and uHealth 9(2):e22601. https://doi.org/10.2196/22601

Kardefelt-Winther D, Rees G, Livingstone S (2020) Contextualising the link between adolescents' use of digital technology and their mental health: a multi-country study of time spent online and life satisfaction. J Child Psychol Psychiatry 61(8):875–889. https://doi.org/10.1111/jcpp.13280

Langarizadeh M, Sadeghi M, As'habi A, Rahmati P, Sheikhtaheri A (2021) Mobile apps for weight management in children and adolescents: an updated systematic review. Patient Educ Couns 104(9):2181–2188. https://doi.org/10.1016/j.pec.2021.01.035

Lau PW, Lau EY, Wong DP, Ransdell L (2011) A systematic review of information and communication technology–based interventions for promoting physical activity behavior change in children and adolescents. J Med Internet Res 13(3):e48. https://doi.org/10.2196/jmir.1533

Lauricella AR, Wartella E, Rideout VJ (2015) Young children's screen time: the complex role of parent and child factors. J Appl Dev Psychol 36:11–17. https://doi.org/10.1016/j.appdev.2014.12.001

Mark AE, Janssen I (2011) Influence of movement intensity and physical activity on adiposity in youth. J Phys Act Health 8(2):164–173

Michie S, Van Stralen MM, West R (2011) The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci 6(1):42. https://doi.org/10.1186/1748-5908-6-42

Michie S, Atkins L, West R (2015) The behaviour change wheel: a guide to designing interventions. Sutton: Silverback Publishing

Ofcom (2019) Children and parents: Media use and attitudes report. Retrieved from https://www.ofcom.org.uk/__data/assets/pdf_file/0023/190616/children-media-use-attitudes-2019-report.pdf. Accessed 11 Nov 2021

Parsons MW, Gardner MM, Sherman JC, Pasquariello K, Grieco JA, Kay CD et al (2022) Feasibility and acceptance of direct-to-home tele-neuropsychology services during the COVID-19 pandemic. J Int Neuropsychol Soc 28(2):210–215. https://doi.org/10.1017/S1355617721000436

Poitras VJ, Gray CE, Borghese MM, Carson V, Chaput JP, Janssen I… Kho ME (2016) Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. Appl Physiol Nutr Metab 41(6):S197–S239. https://doi.org/10.1139/apnm-2015-0663

Ridgers ND, Drehlich M (2021) Youth applications. In: Digital Health (pp. 305–317). Academic Press

Ridgers ND, McNarry MA, Mackintosh KA (2016) Feasibility and effectiveness of using wearable activity trackers in youth: a systematic review. JMIR mHealth and uHealth 4(4):e129. https://doi.org/10.2196/mhealth.6540

Rose T, Barker M, Jacob CM, Morrison L, Lawrence W, Strömmer S et al (2017) A systematic review of digital interventions for improving the diet and physical activity behaviors of adolescents. J Adolesc Health 61(6):669–677. https://doi.org/10.1016/j.jadohealth.2017.05.024

Ruiz JR, Ortega FB, Martínez-Gómez D, Labayen I, Moreno LA, De Bourdeaudhuij I et al (2011) Objectively measured physical activity and sedentary time in European adolescents: the HELENA study. Am J Epidemiol 174(2):173–184. https://doi.org/10.1093/aje/kwr068

Sharaievska I, Battista RA, Zwetsloot J (2019) Use of physical activity monitoring devices by families in rural communities: qualitative approach. JMIR Pediatr Parent 2(1):e10658. https://doi.org/10.2196/10658

Shin M, Hickey K (2021) Needs a little TLC: Examining college students' emergency remote teaching and learning experiences during COVID-19. J Furth High Educ 45(7):973–986. https://doi.org/10.1080/0309877X.2020.1847261

Spina G, Bozzola E, Ferrara P, Zamperini N, Marino F, Caruso C et al (2021) Children and Adolescent's perception of media device Use consequences. Int J Environ Res Public Health 18(6). https://doi.org/10.3390/ijerph18063048

Talarico R, Janssen I (2018) Compositional associations of time spent in sleep, sedentary behavior and physical activity with obesity measures in children. Int J Obes 42(8):1508–1514. https://doi.org/10.1038/s41366-018-0053-x

Verloigne M, Van Lippevelde W, Maes L, Yıldırım M, Chinapaw M, Manios Y et al (2012) Levels of physical activity and sedentary time among 10- to 12-year-old boys and girls across 5 European countries using accelerometers: an observational study within the ENERGY-project. Int J Behav Nutr Phys Act 9(1):34. https://doi.org/10.1186/1479-5868-9-34

World Health Organization (2021) Health for the World's adolescents: a second change in the second decade. Retrived from: https://apps.who.int/adolescent/second-decade/section2/page1/recognizing-adolescence.html#:~:text=Defining%20terms.,the%20age%20of%2018%20years. Accessed 3 May 2021