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The development of a family-based wearable intervention using behaviour change and co-design approaches: move and connect

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ABSTRACT

Background: Previous research has explored the effectiveness of wearable activity trackers (wearables) for increasing child physical activity (PA) levels, but there have been mixed results. The use of theoretical frameworks and co-design techniques are recognised ways of increasing an intervention's acceptability and effectiveness.
Aims: This study aims to use co-design workshops and an evidence-based theoretical framework (the Behaviour Change Wheel) to develop a family-based PA intervention using wearables.
Methods: Three stages of intervention development outlined by the Behaviour Change Wheel were used. Co-design workshops with seven families (11 parents and 12 children) and seven PA experts were conducted where stakeholders discussed how to overcome previously identified barriers to families being active and using wearables. This resulted in the intervention's components being developed, with each component's mechanisms of action (e.g. intervention functions and behaviour change techniques) being retrospectively identified.
Results: The 'Move & Connect' intervention was developed, which targets family PA and wearable use. The intervention takes a flexible approach and includes eight components, including wearable devices (Fitbit Alta HR), support resources, an introductory workshop, collective challenges, goal setting and reviewing, engagement prompts, social support and health-related resources (e.g. educational videos). The intervention incorporates six intervention functions targeting PA and wearable use: education, training, modelling, persuasion, incentivisation and environmental restructuring and 24 behaviour change techniques, including goal setting, social comparison, feedback on behaviour and graded task.
Conclusions: This is the first known study to use an evidence-based framework and co-design to develop a family-based wearable intervention. The identification of the intervention's mechanisms of action will prove useful when implementing and evaluating the 'Move & Connect' intervention and allow researchers to replicate its components.

Introduction

Physical inactivity during childhood is a public health concern,[1,2] with some studies estimating as few as 29% of children are meeting physical activity (PA) recommendations of 60-min of moderate-to-vigorous-intensity PA per day.[3] Approaches to increasing PA are conducted at an individual level, community level and policy level[4] but have had varying success.[5] Advances in technology have led to greater ability to monitor and change movement behaviours, such as PA.[6–8] Technology intervention tools (e.g. apps,[9] pedometers[10]) have previously been implemented in various settings (e.g. school,[11–13] family[14–16]) aimed at increasing child PA levels. Previous research has found that wearable activity trackers (wearables) can increase step counts and moderate-to-vigorous-intensity PA (MVPA) in 5- to 19-year-olds,[17] and their use in the family environment is acceptable and can increase motivation for PA.[14]

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However, there is limited research exploring wearable's ability to increase child and adult PA, when implemented in the family.[17]

The Behaviour Change Wheel

The Medical Research Council (MRC) recommends complex interventions should be developed based on appropriate evidence and theory to clearly understand the intervention's process of change.[18] The Behaviour Change Wheel (BCW) is one framework used to systematically develop behaviour change interventions.[19] The BCW is a synthesis of 19 frameworks and uses the Capability, opportunity, motivation and behaviour (COM-B) model[19] and Theoretical Domains Framework (TDF)[19] to consider how interventions can incorporate functions and behaviour change techniques (BCTs) to change behaviour.[19] The COM-B model suggests a change in capability, opportunity and/or motivation may directly change behaviour or a change in capability or opportunity may indirectly change behaviour via motivation.[19] The TDF is an extension of the COM-B model and further differentiates a set of 14 domains that correspond with capability (knowledge; behavioural regulation; memory, attention and decision process; skills), opportunity (environmental context and resources; social influences) and motivation (goals; optimism; intentions; beliefs about capabilities; beliefs about consequences; professional/social role and identity; reinforcement; emotion).[19] The BCW develops 'theory-based' interventions by systematically linking barriers of a behaviour (identified by the COM-B model and TDF) to intervention functions and BCTs to change the behaviour.[19,20] This compares to 'theory-inspired' interventions, where elements of a theory are loosely embedded within an intervention, or it is unclear whether theoretical underpinnings were used in the development of the intervention (e.g. theory could be referenced retrospectively).[19,20] The BCW outlines three stages of intervention development, which have previously been used to develop interventions aimed at increasing PA[15] and reducing sedentary behaviour[21] in adults.

Co-design

Limitations of evidence- and theory-based interventions (e.g. using the BCW) are that they do not always translate into practice, which is known as the 'research-practice gap'.[22] A way of overcoming this gap is to engage intervention target users in the development of the intervention, treating them as equal partners to researchers, practitioners and other experts in the field.[22] Examples of such participatory research methods are co-production, co-creation and co-design.[23,24] These terms are often used interchangeably, with no clear difference in definitions between them.[25] The term co-design will be used in the present study, consistent with previous research using similar methodology (e.g. workshops).[26,27] Co-design techniques (e.g. workshops, forums, surveys[28]) may increase the efficacy of behaviour change interventions[25,28] and enable researchers to examine whether interventions are acceptable, feasible, enjoyable, motivating and informative for the target group.[29] Previous research has identified several barriers to implementing family-based wearable interventions, such as technical difficulties, inability to interpret wearable outputs and use wearable features.[14,30,31] Combining theory-based and co-design methodology, within the present study, is expected to increase the efficacy of the newly developed intervention and overcome previously identified barriers to families using wearables.

This study aims to use co-design workshops and an evidence-based theoretical framework (the three stages outlined by the BCW[19]) to develop a family-based intervention using wearable activity trackers.

Methods

This study used participatory methods to develop a family-based wearable intervention, informed by co-design workshops, previous research[14,17] and the BCW.[19]

Recruitment and stakeholders

Stakeholders were split into two groups: (1) families and (2) PA experts.

- Families: Families (parents and children) were recruited using convenience sampling (e.g. existing connections and social media posts). Families were eligible to participate if they (1) had at least one child, aged 5 to 9 years; (2) considered at least one member to not participate in regular PA; and (3) had access to Wi-Fi/internet and a smart device to participate in the online workshops. Online workshops were chosen due to COVID-19 restrictions at the time of this study (social distancing measures were in place). Families with 5- to 9-year-olds were selected as few wearable-based interventions have targeted this age group,[17] and preliminary research, which informed the co-design workshops, were informed by an acceptability study targeting families with 5- to 9-year-olds.[14]
- PA experts: Experts were purposefully recruited (via existing connections) if they had experience in one or more of the following areas:
  1. Development or design of a PA intervention.
  2. Implementation or evaluation of a PA intervention.
  3. Using wearable activity trackers as a feasibility or intervention tool.
  4. Working with children and/or families in a research or community setting, such as (but not limited to) community workers or practitioners.

Experts' eligibility against these criteria was assessed via the expert's online bibliographies, publication records and/or informal correspondence with the study's research team to discuss their previous and current experience and/or job role(s).

Ethical approval

This study was approved by Loughborough University Ethical Approvals (Human Participants) Sub-Committee (REF: 2021-29221-5132). All family members and experts provided informed consent (parents on behalf of children), and children provided their own assent.

Materials and procedure

Demographic questionnaire

All workshop participants completed a demographic questionnaire before attending the online workshops.

- Families: All family member's age, gender, ethnicity, home postcode and wearable use were collected. Self-reported PA levels, using the short version of the International PA Questionnaire (IPAQ-SF[32]), were also collected (parental report for all children). The IPAQ-SF has previously been found to have acceptable reliability and validity for adults and children.[33,34] The IPAQ-SF documents the number of days (in the last 7 days) spent participating in moderate PA and vigorous PA (frequency 0—7) and the average number of minutes spent during those days (duration; 10-min increments from 10 min to more than 120 min). The number (percentage) of family members

meeting the UK's Chief Medical Officers' PA recommendations of an average 60 min of MVPA per day (3–18 years) and an average of 150 min of moderate physical activity (MPA) or 75 min of vigorous physical activity (VPA) per week (≥18 years) were calculated. Adults also reported their highest educational qualification (none, General Certificate of Secondary Education, Advanced level, National Vocational Qualification level 4, Bachelor's degree, Master's degree, doctorate or other).

- PA experts: Expert's ethnicity, highest educational qualification, job role, work setting/sector and wearable use were collected.

Intervention development

This study followed the three stages of intervention development outlined by the BCW[19] (Fig. 1). Stage 1 (understanding the behaviour) was conducted before the co-design workshops, and Stages 2 (identify intervention options) and 3 (identify content and implementation option) were conducted after the co-design workshops.

Stage 1. understand the behaviour (steps 1–3). The guidance outlined as part of the BCW was followed to address steps 1, 2 and 3.[19] Step 1 required the present research team to operationalise (1) the target individual, group or population involved in the behaviour; and (2) the behaviour itself.[19] The research team discussed the following questions, as recommended by the BCW:[19] (1) What are the behaviours? (2) Who is involved in performing the behaviour? (3) Where does the behaviour occur?

The first author (A.V.C.) then completed step 2 by generating a list of potential behaviours that may influence the selected target behaviour(s). The behaviours were then reviewed by the wider research team, and the following discussed, as recommended.[19]

1. The likely impact if the behaviour were to be changed.
2. How easy it would be to change the behaviour.
3. The centrality of the behaviour within the system of behaviours. The positive 'spill-over' effect if that behaviour were to be changed.
4. How easy it is to measure the behaviour.

The target behaviours were then further refined, collaboratively by the research team, using the following questions (step 3):[19] (1) *Who* needs to perform the behaviour? (2) *What* does the person need to do differently to achieve the desired change? (3) *When* will they do it? (4) *Where* will they do it? (5) *How often* will they do it?

Stage 1. identify what needs to change (step 4). The final step of stage 1 was to identify what needs to change for families to use

wearables to increase their PA. The findings from previous research[14,17] were used to form the basis of the co-design workshops. A.V.C. pooled together the findings from previous work, which included a systematic review exploring the acceptability, feasibility and effectiveness of wearables for increasing PA in 5- to 19-year-olds[17] and a 4-week study exploring families' acceptability of using wearables.[14] Key findings from these studies were aligned with components of the COM-B model[19] and TDF,[35] and A.V.C. generated a list of barriers preventing families from using wearables to be physically active. A.V.C. and H.A.J.B. discussed each barrier and came to a final decision for each barrier: 'very promising', 'quite promising', 'unpromising but worth considering' or 'unacceptable'.[19] Previous research also reported families' suggestions for future wearable interventions.[14,17] These intervention suggestions were evaluated by A.V.C. and H.A.J.B. using the 'APEASE' criteria (affordability, practicability, effectiveness and cost-effectiveness, acceptability, side-effects, equity). These evaluation criteria were used to decide which barriers and intervention suggestions were presented as vignettes in the co-design workshops. Based on the duration of the workshops (1.5 h each), it was anticipated that between eight to ten vignettes could be presented.

Co-design workshops. All families and PA experts took part in two 1.5-h online workshops (using the online teleconferencing platform, Zoom). Family and expert workshops were conducted separately, with both family workshops taking place before the two expert workshops. All family and expert workshops were led by A.V.C. and facilitated by S.A.C. and D.D.B., were audio recorded and transcribed by A.V.C.

Family workshops
Workshop 1

Families were presented with vignettes that displayed family-related barriers to the target behaviours (PA and wearable use) and intervention suggestions. Vignettes are stories or descriptions (e.g. textual or pictographic form) of hypothetical characters in circumstances or scenarios.[36,37] Their advantages include reducing pressure and social desirability and allowing participants to lead their own discussions and interpretations of the scenarios presented.[36] Participants were asked to discuss what the intervention could include to overcome the presented barriers and whether they would incorporate the intervention suggestions into the intervention. At the end of workshop 1, family members were encouraged to consider the intervention's name. These were discussed in workshop 2. After workshop 1, A.V.C. and H.A.J.B. synthesised the key findings from workshop 1 by grouping together families' suggestions for each vignette presented.
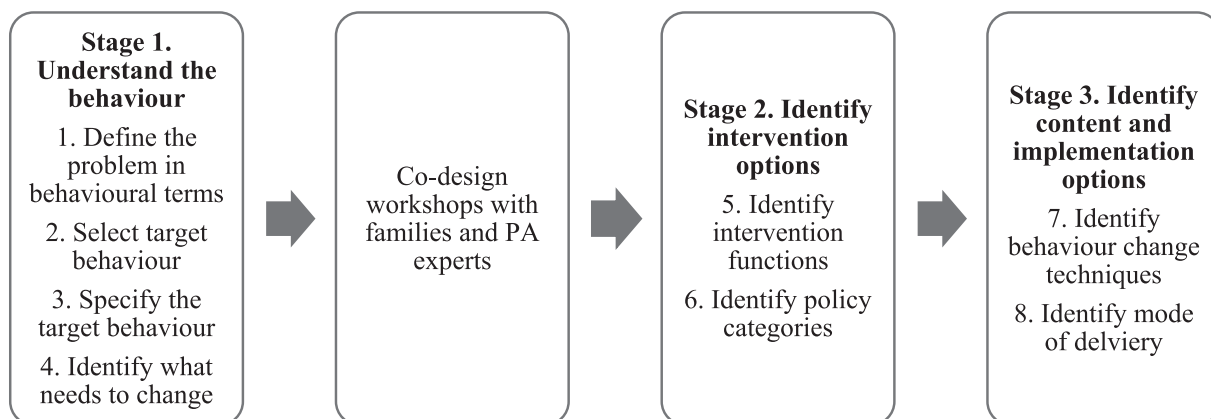

Fig. 1. Stages of intervention development outlined by the Behaviour Change Wheel,[19] with the addition of co-design workshops, used in the present study.

Workshop 2

Suggestions for implementing intervention components discussed in workshop 1 were re-presented in the second workshop, and family members were asked to refine the intervention components (e.g. any additions, adaptations or removal of intervention components). Family members were then asked about their suggestions for the intervention name. A.V.C. and H.A.J.B. pooled together key findings from both family workshops to inform the expert co-design workshops.

Expert workshops. Both expert workshops followed the same format as the family workshops but included the addition of families' intervention suggestions and responses to the vignettes. Experts were told the purpose of consulting with them was to consider how families' intervention suggestions may be adapted to increase the intervention's effectiveness, sustainability and scalability. Experts were encouraged to discuss their knowledge and experience of implementing similar intervention components, particularly considering what has, and has not, been successful in their previous research.

Stage 2. Identify intervention options. The remaining steps took place after the co-design workshops. All workshop content (families and experts) were transcribed by A.V.C. and summarised using three stages of thematic analysis[38] by A.V.C. and H.A.J.B. A.V.C. and H.A.J.B. familiarised themselves with the transcriptions and used NVivo software (QSR International, Melbourne, Australia) to independently develop inductive free codes by coding each line (family and expert responses) according to its meaning. Free codes were then developed inductively into themes, which reflected intervention components. A.V.C. and H.A.J.B. discussed each theme and collaboratively refined them, resulting in the intervention's components. A.V.C. and H.A.J.B. summarised the key intervention components and used the 'APEASE' criteria[19] (same as step 4) to determine which were to be included and excluded in the intervention. This included considering whether the intervention components were affordable, practicable, effective, cost-effective, acceptable, equitable or would result in any negative side-effects, when considering the availability of funds and resources to implement the intervention in the near future.

Stage 2. Identify intervention functions (step 5). A.V.C. and H.A.J.B. deductively coded for intervention functions present within each intervention component (including the wearable; Fitbit Alta HR), using the nine functions outlined by the BCW (education, persuasion, incentivisation, coercion, training, restriction, modelling, enablement and environmental restructuring).[19] A.V.C. and H.A.J.B. were provided with definitions of each function, and coding was conducted independently. Once completed, the results were discussed, and any disagreements resolved. To code for intervention functions in the wearable, A.V.C. and H.A.J.B. wore and interacted with the Fitbit Alta HR, and its partnering app for four consecutive weeks, and carried out the same coding procedure described previously.

Stage 2. Identify policy categories (step 6). As the intervention was intended to be implemented at an individual level, the authors did not identify policy categories.

Stage 3. Identify content and implementation options

Stage 3. Identify BCTs (step 7). A.V.C. and H.A.J.B. deductively coded for BCTs present within each intervention component, and the Fitbit Alta HR, using the 93 BCTs outlined by the BCTTv1[19,39] (part of the BCW). A.V.C. and H.A.J.B. were provided with definitions of each BCT and had completed BCTTv1 online training (https://www.bct-taxonomy.com/), which included tasks to identify BCTs present in interventions. Coding was conducted independently and, once completed, resolved any disagreements (same as step 5). To code for BCTs in the wearable, A.V.C. and H.A.J.B. wore and interacted with the Fitbit Alta HR and its partnering app for four consecutive weeks and carried out the same coding procedure described above (similar to Stage 2, Step 5).

Stage 3. Identify the mode of delivery (step 8). The mode of delivery for each intervention component was discussed with families and experts throughout the co-design workshops. If the delivery of intervention components was unclear, these were discussed amongst the current research team (A.V.C., H.A.J.B., D.D.B., S.A.C. and S.C.).

Results

Preworkshops

Define the problem in behavioural terms and select and specify the target behaviour (steps 1—3)

Table 1 outlines the results from steps 1, 2 and 3. Two target behaviours were selected: (1) PA and (2) wearable use. Physical activity was selected, as few children[3] and adults[40] are meeting PA guidelines, and wearable use was selected as previous research has reported children and adults experience a 'novelty effect' (reduction in use after using a wearable for a period due to loss of interest; ~2—4 weeks[41]) when using wearables.[14,17,42] Potential behaviours impacting PA and wearable use in children and adults were

Table 1
Defining and specifying the intervention's target behaviours: PA and wearable use.

Target behaviour 1	Increase family PA to meet the guidelines of ≥60 min of MVPA/day for children and ≥150 min of MPA or ≥75 min of VPA/week for adults. Encourage family co-participation in PA, where possible.
Who needs to perform the behaviour?	All family members. Families must live in Bradford, West Yorkshire, UK.
What does the person need to do differently to achieve the desired change?	Participate in the intervention and use the Fitbit to support this change.
When will they do it?	Habitual. Anytime that works for their family.
Where will they do it?	Anywhere.
How often will they do it?	Every day (for children) and weekly (for adults). Co-participation in PA when possible.
Target behaviour 2	Encourage wearable use.
Who needs to perform the behaviour?	All family members.
What does the person need to do differently to achieve the desired change?	Use the Fitbit and Fitbit app.
When will they do it?	Daily.
Where will they do it?	Everywhere.
How often will they do it?	Every day.

MVPA, moderate-to-vigorous-intensity physical activity; PA, physical activity.

considered based on previous research identifying key correlates and determinants of PA and wearable use.[14,17,43–45] Biological (age, sex), sociocultural (social support), socio-economic (household income) and behavioural (active travel) correlates and determinants were identified. The authors opted for the intervention's target behaviours to be broad and refer to global recommendations where possible (e.g. meeting PA guidelines; Table 1), as vignettes presented in the co-design workshops were used to ensure the intervention's components and delivery (e.g. active travel) were led by families and experts, rather than pre-determining its components.

Selecting workshop content based on 'what needs to change' (step 4)

Supplementary Tables S1 and S2 demonstrate the selection process used to determine which barriers and intervention suggestions were included in the workshops, as vignettes. In total, 26 barriers were identified ($n = 14$ for PA, $n = 12$ for wearable use). Seven intervention suggestions were identified in the previous research.[14,17] Nine vignettes were presented in family workshop 1 and across both expert workshops. These vignettes reflected eight barriers (PA: $n = 7$, wearable use: $n = 1$) and six intervention suggestions. Barriers included in the co-design workshops reflected psychological capability (knowledge: $n = 2$; memory, attention and decision processes: $n = 1$), social opportunity (social influences: $n = 1$); automatic motivation (emotion: $n = 1$); and reflective motivation (intentions: $n = 1$, goals: $n = 1$, optimism: $n = 1$).

Co-design workshops

Stakeholder demographics

Seven families, including seven mothers, four fathers and 12 children (four boys, eight girls), and seven PA experts took part in the workshops. Stakeholder demographics are presented in Tables 2 and 3.

The developed intervention and its mechanisms of action (steps 5, 7 and 8)

Based on families' suggestions, the 'Move & Connect' intervention was developed:

"Fitbit Connect" because I felt like with the Fitbit (wearable brand) it allows you to connect with yourself by looking at what you're doing and what you could be doing to reach those goals but also connecting with other people" (Mother)

The 'Move & Connect' intervention is designed to be implemented at an individual level, with a suggested pilot duration of 12 weeks. The intervention will take a 'flexible' approach, which provides families with the tools (e.g. the Fitbit) to increase PA when it works best for them:

"It's quite nice to have something where I don't need to commit to anybody else" (Father, Family 1); "Increasing the flexibility of interventions, so there are less rigid fixed components" (Senior Research Fellow); "It's just giving them the tools and letting them fit it in to their schedule" (Senior Research Associate).

Table 4 displays the 'Move & Connect' intervention components and their corresponding intervention functions and BCTs. The results of the thematic analysis, which reflect each intervention component, is presented in Supplementary Table S3. The 'Move & Connect' intervention is a multicomponent intervention with eight components, which content aligns with six

Table 2
Family demographics.

Demographics	Parents ($n = 11$)	Children ($n = 12$)[a]
Age		
Mean (SD)	42 (5.68)	8 (4.01)
Range	32—50 years	5—18 years
Ethnicity, *n* (%)		
White British	7 (64%)	6 (50%)
Pakistani Heritage	4 (36%)	6 (50%)
Wearable use, *n* (%)		
Currently use	7 (64%)	4 (33%)
Previously used	2 (18%)	6 (50%)
<1 month	1	4
1—5 months	2	4
6—11 months	1	1
1—2 years	2	1
>2 years	3	0
Never used	2 (18%)	2 (17%)
Meeting physical activity guidelines, *n* (%)[b]		
Yes	2 (18%)	5 (42%)
No	9 (82%)	7 (58%)
Index of multiple deprivation, *n* (%)[c]		
Decile 1—3 (most deprived)	5 (71%)	
Decile 4—7	1 (14%)	
Decile 8—10 (least deprived)	1 (14%)	
Highest educational qualification, *n* (%)		
Advanced level (A level)	2 (18%)	
Undergraduate degree	2 (18%)	
Professional degree	2 (18%)	
Master's degree	4 (57%)	
Doctoral degree	1 (14%)	

SD, standard deviation.
[a] Includes a child who was 18 years.
[b] Child: ≥60 min of MVPA/day, adult: ≥75 min of VPA/week or ≥150 min of MPA/week.
[c] Index of Multiple Deprivation based on home postcode (per family, $n = 7$).

intervention functions (education, training, modelling, persuasion, incentivisation and environmental restructuring) and 24 BCTs. Most intervention components are intended to be delivered using an invitation-only group developed by the research team on the Fitbit app (the 'hub').

Discussion

This is the first known study to use the BCW and co-design workshops to develop a wearable intervention, targeting family

Table 3
PA expert demographics.

	Experts ($n = 7$)
Ethnicity, *n* (%)	
White British	5 (71%)
Pakistani Heritage	1 (14%)
Black British	1 (14%)
Wearable use, *n* (%)	
Currently use	3 (43%)
Previously used	3 (43%)
1—2 years	4
>2 years	2
Never used	1 (14%)
Job role, *n* (%)	
Senior research fellow/associate	5 (71%)
Community engagement manager	1 (14%)
Community PA facilitator	1 (14%)
Job sector, *n* (%)	
University	3 (43%)
National Health Service (NHS)	4 (57%)
Highest educational qualification, *n* (%)	
Undergraduate degree	2 (29%)
Doctoral degree	5 (71%)

Table 4

The 'Move & Connect' intervention components, corresponding intervention functions, BCTs and supporting quotes.

Target behaviour(s)	Intervention component	Targeted COM domain(s)	Targeted TDF domain(s)	Intervention function(s)	Behaviour change technique(s)	Supporting quotes
PA and wearable use	1. **Introductory workshop** (1) An explanation of the intervention and why it is important to take part (e.g. importance of PA). (2) Practical support to link the Fitbit's to family member's smart devices. (3) How to navigate the intervention's hub. (4) Setting individual and family PA goals. (5) Answer a short series of questions: (1) What physical activities do you enjoy doing as a family? (these include any type of movement), (2) When and how (e.g. duration/frequency, context) could you find the time to do these activities?	C, M	Knowledge Skills Goals Decision processes	Education Training	Goal setting (behaviour), action planning, information about health consequences, credible source, social support (practical)	*"Part of a workshop where you get them together to form action plans"* (Senior Research Associate) *"You can't just give them the Fitbit and ask them to go away and use it you need to give them a bit of education on how to use it, so is it part of a workshop where you get them together to form action plans"* (Senior Research Associate)
Wearable use	2. **Wearable support resources** (1) Bullet-point lists with images to demonstrate how to use the Fitbit (syncing, charging) and basic features including what each PA symbol means and how to change goals. (2) Five short videos (~5 min each) demonstrating how to use some of the Fitbit's advanced features. (3) Tip of the week' — each week a useful tip of how to use the Fitbit will be posted on the hub. (4) Families will have the option to request guidance on using the Fitbit from the research team (via the hub, phone, or video call).	C	Knowledge Skills	Education Training	Instruction how to perform the behaviour, demonstration of the behaviour, social support (practical)	*"Making it clear that this watch is more beneficial with the app"* (Mother) *"You could click a certain button on the screen and it could show you a little video on how to do it"* (Male, 6 years) *"In the app if you had a tip of the day so like you know "don't forget that if you're going run make sure you press this button" or "Fitbit also measures this if you're doing this exercise"* (Father) *"Perhaps maybe a YouTube video because you could learn off somebody else"* (Female, 11 years)
PA	3. **Healthy behaviours resources** (1) Bullet-point lists with images to demonstrate the importance of PA, such as the benefits of PA, how the Fitbit can help families monitor their PA, and some family friendly physical activities to try. Reliable sources (e.g. Government website, information from peer reviewed papers) will be referred to. (2) Five short videos/webinars (~5 min each).	C, M	Knowledge Beliefs about consequences	Education Persuasion	Information about health consequences, information about emotional consequences, credible source	*"I think the actual physical benefits would be good as well because you actually know you're doing your body some good as well"* (Female, 11 years) *"It has to be something that is very visual"* (Mother) *"What does 10,000 steps or 5000 steps means to them … what do I need to know on my tracker that will let me know I'm doing something that is affecting my health"* (Community Engagement Manager)
PA	4. **Reviewing and amending PA goals** Family members' PA levels, such as step count and/or active minutes from the past 2 weeks, will be extracted via Fitbit's database. Recommended goals will be calculated using a 'rank-order percentile algorithm', which requires the researcher to rank behaviour from lowest to highest and calculate a new goal based on the 60th percentile.[46] Each family will receive an overview of their PA levels, with an indication as to whether they are performing above or below the average of the intervention. This will include an encouraging message and prompt the family to refer to the brief action plan created in the workshop. Family members will be provided with a recommendation to change their PA goal(s) and an image of how to do this.	C, M	Knowledge Goals Behavioural regulation Intention	Education Persuasion Modelling	Review behaviour goal(s), discrepancy between current behaviour and goal, information about others' approval, social comparison, feedback on behaviour, action planning	*"There's a before benchmark so this is what you were doing and, in a few weeks, look at it and say this is how far you've come"* (Father) *"There should be something where you can adjust the goal for yourself so how many steps"* (Female, 18 years) *"It's about tailoring the message you know "don't worry, keep going", "we all have slip ups" those kind of messages and motivational messages so if they are at the 15,000 steps … "you're doing great, "keep it up", "let's keep moving forwards" just as clear and simple as possible but motivating"* (Senior Research Associate) *"Rather than giving them specific details you could say "you're slightly above or below average this week, keep it up!" rather than the specific*

Table 4 (continued)

Target behaviour(s)	Intervention component	Targeted COM domain(s)	Targeted TDF domain(s)	Intervention function(s)	Behaviour change technique(s)	Supporting quotes
						details of all the numbers and percentiles" (Senior Research Fellow)
PA	**5. PA Challenges** Challenges will reflect real-life destinations, with a particular focus on local areas (e.g. X number of steps = the perimeter of a local park). Families will be made aware of the challenge via the intervention's hub. Challenges will be conveyed as 'levels', as challenges will get increasingly more demanding, and will start with 'steps' then move to 'active minutes'. This was chosen to encourage families to perform activities that are reflective of MVPA. Examples of how to obtain active minutes will be provided via an image demonstrating activities that may result in achieving active minutes. Family members will be instructed that they must participate in the activity for at least 10 continuous minutes for the active minutes to be recognised by the Fitbit. Virtual rewards will be received once the challenges have been completed.	M	Goals Reinforcement Intentions	Incentivisation Persuasion	Graded tasks, goal setting (outcome), non-specific reward, non-specific incentive, review outcome goals	*"Can your family walk the length of India or something like that and everybody works together"* (Mother) *"You could say walk twice around [a local park] and that's the same as doing x that might be quite motivating"* (Father) *"If you achieve all your badges you move on to the next level"* (Female, 8 years) *"New challenges every month I think is a really important one, as new and as fresh as possible, and adding some gamification to it especially for kids"* (Senior Research Associate) *"The beginning of those being step-based and then progress that to be more difficult which might then be active minutes"* (Senior Research Fellow)
PA	**6. Recommend a friend or family** Families will have the chance to recommend a friend/family member or family to join the intervention. Families will be encouraged to recommend individuals that they are already active with or who can provide support/encouragement for their family to be active.	O, M	Social influences Environmental context	Environmental restructuring	Social support (unspecified)	*"So you could link your family members to yours so then you could like send them a message or something"* (Female, 8 years) *"… Like hey do you want to play, do a game sort of thing?"* (Mother) *"Encourage participants to encourage their existing friends of wider family to take part in this with them"* (Senior Research Fellow)
Wearable use	**7. Engagement prompts** Engagement prompts will be sent if a family member takes <1000 steps per day for nine of 14 days (2 weeks). Prompts will first be sent via a direct (private) message on the hub, and if no response is received or engagement does not increase, a text message will be sent. Prompts will be delivered every 2 weeks (if necessary) and sent at the start of the week.	O, M	Emotion Social influences	Persuasion	Feedback on behaviour, prompts/cues	*"Maybe if there's been a couple of hours with no activity you could send a prompt"* (Mother) *"I don't know if you could detect when people aren't engaging and only send prompts then"* (Mother)
PA	**8. Wearable device (Fitbit Alta HR)**	C, O, M		Education Incentivisation Modelling Environmental restructuring	Goal setting (behaviour), goal setting (outcome), discrepancy between current behaviour and goal, feedback on behaviour, self-monitoring of behaviour, self-monitoring of outcomes of behaviour, feedback on outcomes of behaviour, social support (unspecified), instruction on how to perform the behaviour, information about health consequences, information about emotional consequences, demonstration of behaviour, social comparison, credible source, non-specific reward, non-specific incentive, reward (outcome), rewarding completion	

C, capability; O, opportunity; M, motivation; TDF, theoretical domains framework.

PA.[17] The resulting 'Move & Connect' intervention is a multicomponent flexible intervention targeting family PA and wearable use via education, training, modelling, persuasion, incentivisation and environmental restructuring and 24 BCTs. The intervention includes a wearable (Fitbit Alta HR), alongside additional components such as collective challenges, setting and reviewing goals, an introductory workshop and wearable and health-related resources (e.g. educational videos).

Intervention development process

The BCW was a useful intervention development framework, as it enabled previous research[14,17] to be systematically embedded within the process and prompted regular refinement of intervention components (e.g. using the APEASE criteria).[19] The eight steps of the BCW enabled the 'Move & Connect' intervention's target behaviours to be specified and mechanisms of action (e.g. intervention functions and BCTs) to be identified.[19] By using this approach, the intervention is expected to support families' capability, opportunity and motivation for PA and wearable use. The BCW is a comprehensive framework,[19] and previous research has reported difficulties selecting the most appropriate intervention functions and BCTs to be embedded within an intervention.[21,47] The present study engaged the intervention's target users (families) in the development process and retrospectively identified the 'Move & Connect' intervention's mechanisms of action based on family and experts' suggested intervention components. This overcame previous difficulties of selecting an intervention's mechanisms of action from the comprehensive list included as part of the BCW and only embedded those that were deemed appropriate by stakeholders. Indeed, using co-design techniques with family members and experts within the current intervention development process may reduce the 'research-practice gap',[22] by considering stakeholders' knowledge and experiences that may influence the interventions acceptability and sustainability.[29] Previous research has similarly integrated evidence from numerous sources, such as systematic reviews, qualitative research and expert opinion (like this study), and reported improvements in intervention acceptability and efficacy.[48] Indeed, in the current intervention development process, families and experts were able to shed light on what intervention components to include to overcome acceptability issues when using wearables, which may not have been considered otherwise (e.g. implementing collective challenges compared with competitions; recommending a family or friend to join the intervention). Although few studies have empirically evaluated the effectiveness of using co-design techniques to develop behaviour change interventions,[28] the partnership between co-design techniques and theoretical underpinnings forms part of the MRC's core elements of intervention development (engage stakeholders, develop an intervention based on research evidence and theory).[18] Thus, this approach may also provide opportunities to successfully secure funding to implement and evaluate the 'Move & Connect' intervention.

Intervention components, functions and BCTs

Some of the 'Move & Connect' intervention components are similar to previous interventions using wearables to increase child or adolescent PA levels.[17] Similar intervention components, such as step challenges and reviewing PA progress,[49,50] increased adolescent step counts[49] and MVPA.[50] The proposed 'Move & Connect' intervention also incorporates more BCTs than typically found in wearable-based interventions.[17] On average, wearable interventions incorporate eight BCTs, with multicomponent interventions incorporating an average of 10 BCTs (range: 2—12

BCTs).[17] This compares to 24 in the 'Move & Connect' intervention. Identifying the 'Move & Connect' intervention's mechanisms of action, in the present study, can provide an indication as to 'how' and 'why' an intervention works or does not work,[51] aids replicability and provides justification for modifying intervention components based on their effectiveness.[51,52] The 'Move & Connect' intervention must be piloted to explore its feasibility, from an implementation and evaluation perspective, and to examine whether the number or type of intervention functions or BCTs impacts its potential effectiveness.

Previous interventions targeting child or family PA levels have been limited in their long-term effectiveness,[5] including those incorporating wearables as intervention tools.[17] Therefore, the sustainability of the 'Move & Connect' intervention was important to consider throughout the development process (e.g. within the expert workshops). The flexible nature of the intervention may be beneficial for its sustainability and adherence, as parents often report household, family and occupational responsibilities as barriers to being physically active.[14,53] Family-based interventions developed solely by researchers have been criticised for not allowing flexibility for families to engage with intervention components.[54] Allowing families to flexibly engage with the 'Move & Connect' intervention will enable them to use the intervention tools when it is most convenient for them, which may help overcome previously identified external barriers to PA (e.g. time).[14] One potential drawback of implementing a flexible intervention is that engagement with intervention components may differ between families. This means that the intervention's mechanisms of action (identified functions and BCTs) may also differ between families, and there are no consistent mechanisms that are used by all. Therefore, the ability to measure families' engagement with the intervention components, including the wearable itself, may be crucial. Once implemented and evaluated, the intervention's effectiveness may be stratified based on the type and amount of engagement they had with the intervention's components.

Targeting wearable use, as well as PA, in the 'Move & Connect' intervention may be important for sustaining families' engagement with the intervention. The novelty effect has previously been identified as a barrier of wearable use.[14,17,41] Ridgers et al.[41] recently suggested an 'adherence window', which may reflect a window of opportunity (2—4 weeks) for researchers to encourage long-term wearable use. By regularly monitoring families' wearable use and providing prompts, alongside tailored messages, this may encourage wearable use and engagement with the intervention. To our knowledge, this has not been considered in wearable interventions targeting child PA.[17] The 'Move & Connect' intervention must be piloted to explore its acceptability, feasibility and fidelity. To potentially increase the intervention's effectiveness, a whole systems approach is likely required. A whole systems approach considers a behaviour's interactive, ongoing and dynamic complexities with other behaviours and settings.[55] Whole system approaches encourage stakeholders to share understanding, consider the integration of behaviours and target where to intervene that may result in potential 'spill-over effects'.[55–57] A benefit of the 'Move & Connect' intervention is that it can be easily integrated within existing interventions and initiatives, if found to be effective in future trials.

Future directions

Following recommendations outlined by the MRC,[18] the 'Move & Connect' intervention will be implemented and evaluated to explore its acceptability, feasibility and preliminary effectiveness on families' PA levels and physical health (e.g. body mass index, body fat percentage, waist circumference) using a pilot randomised

controlled trial lasting 12-weeks. A multidisciplinary team will collaborate to plan, design, and conduct the implementation and evaluation of the intervention.[18] Families from deprived backgrounds will be recruited (reflecting the demographics of families participating in the present study), and facilitators, such as community workers, will be trained to deliver the 'Move & Connect' intervention. Exploring the feasibility and fidelity of facilitators (vs researchers) implementing the current intervention will provide insights into its longevity. If the 'Move & Connect' intervention is feasible and effective, a definitive longer term trial will be conducted. There is potential for the intervention to be adapted and expanded into other settings and with other target users, such as clinical settings, following further participatory action research.

Strengths and limitations

The strengths of this study include its systematic development using theoretical underpinnings and co-design techniques with families and experts. Displaying barriers to family PA and wearable use via vignettes was a strength of this study. Vignettes can reduce social desirability and enable discussions in a non-confrontational way.[36] The accounts provided by families were typically in the first-person, which demonstrated how the vignettes were internalised and enabled families to interpret the scenarios in a way that reflected their own family circumstances.[36] However, different perspectives meant it was difficult to refine intervention components by balancing evidence-based knowledge (PA experts) and acceptability (families). This is recognised as a difficulty of conducting multistakeholder work.[58] One way to consider the alignment of views is by using a Delphi method.[59] The Delphi method is a systematic process that results in a consensus of expert opinion via several stages of data collection (e.g. questionnaires).[59] Previous studies have used multiple questionnaires to refine intervention components.[60] It may have been beneficial to use Delphi methods to follow-up with families and experts after their workshop participation. However, Delphi methods are burdensome, and dropout rates can range from 25% to 60%.[61,62] A convenience sampling strategy was used to recruit families. Therefore, the families involved in the co-design workshops may already have the capability, opportunity, and/or motivation to be active or participate in behaviour change initiatives. Gaining more families perspectives via public and patient involvement work will be crucial before implementing and evaluating the 'Move & Connect' intervention. Furthermore, most families lived in deprived areas (Index of Multiple Deprivation deciles 1—3). This not only limits the generalisability of the intervention but also allows the intervention to be implemented in such areas, where PA may be low.[63] Although the Index of Multiple Deprivation provides insight into area-level socio-economic status, the cost of wearables has previously been identified as a barrier of adults using wearables.[64] Thus, collecting additional demographic data, such as household income, when implementing and evaluating the 'Move & Connect' intervention could provide further insights into the sustainability of the intervention.

Conclusions

This is the first study to use the BCW and co-design to develop an evidence-informed family-based wearable intervention (the 'Move & Connect' intervention). This study demonstrates how the integration of previous research, theoretical underpinnings and stakeholder involvement can be used to develop behaviour change interventions and identify its mechanisms of action. Future research may wish to apply the same methodology to enable a systematic way of evaluating and replicating its intervention components. Further work is needed to examine the feasibility and acceptability of implementing and evaluating the 'Move & Connect' intervention, along with ascertaining its potential effectiveness.

Author statements

Competing interests

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.018.

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