

Using the Behaviour Change Wheel to co-design a sedentary behaviour intervention in individuals with spinal cord injury

Daniel L Cooper ^{a,b}, Alyson Warland ^{a,c}, Emma Norris ^c, Cherry Kilbride ^{ac}, Sue Paddison ^d, Daniel P Bailey ^{a,b}

^a Centre for Physical Activity in Health and Disease, College of Health, Medicine and Life Sciences, Brunel University of London, Kingston Lane, Uxbridge, UB8 3PH, United Kingdom

^b Department of Sport, Health and Exercise Sciences, Brunel University of London, Kingston Lane, Uxbridge, UB8 3PH, United Kingdom

^c Department of Health Sciences, Brunel University of London, Kingston Lane, Uxbridge, UB8 3PH, United Kingdom

^d London Spinal Cord Injury Centre, Royal National Orthopaedic Hospital NHS Trust, Brockley Hill, Stanmore, HA7 4LP, United Kingdom

Corresponding author: Daniel L Cooper, daniel.cooper2@brunel.ac.uk

Please note that this article is a preprint and is currently being peer-reviewed.

Abstract

Purpose: There is a lack of sedentary behaviour interventions for individuals with spinal cord injury. Interventions designed for non-disabled individuals are unlikely to be generalisable to wheelchair-users with paraplegia, meaning a tailored approach is needed.

Objective: This study aimed to co-design a sedentary behaviour intervention using the Behaviour Change Wheel (BCW) for manual wheelchair-users with paraplegia.

Methods: An iterative co-design approach was employed across workshops with 10 individuals with paraplegia, 13 healthcare professionals and four community caregivers. Initial workshops focused on barriers and facilitators to reducing and breaking up sedentary behaviour, and possible intervention options. This informed initial intervention concepts, which were mapped to BCW constructs and behaviour change techniques. In follow-up workshops,

the acceptability, practicability, effectiveness, affordability, safety/side-effects, and equity of

NOTE: This preprint reports new research that has not been certified by peer review and should not be used to guide clinical practice.

each intervention component was assessed to refine concepts and design an intervention protocol. Data was analysed using the framework method via inductive and deductive coding in context of the BCW.

Findings: A multi-component intervention was co-designed and includes (1) a wearable activity tracker to facilitate reminders to be active and give feedback on physical activity, (2) an educational booklet to overcome lack of knowledge around sedentary behaviour, (3) goal setting, (4) one-to-one motivational support from a trained individual, (5) a peer support group and (6) activity tools, including a portable hand cycle and exercise bands.

Conclusions: A novel intervention targeting sedentary behaviour has been developed for individuals with paraplegia. The combination of co-design with the BCW likely optimises the intervention's acceptability and effectiveness, which now requires evaluation.

Keywords: Behaviour Change Wheel; Cardiovascular disease; Co-design; Intervention; Paraplegia; Physical activity; Sedentary behaviour

Introduction

Individuals with spinal cord injury (SCI) are at significantly greater risk of cardiovascular disease (CVD) than the general population¹. This increased risk may be a result of physical inactivity, reduced metabolic rate, accumulation of body fat and sarcopenia after injury². Interventions to reduce CVD risk are, therefore, needed in individuals with SCI.

Greater levels of sedentary behaviour, defined as any waking behaviour characterised by an energy expenditure of ≤ 1.5 metabolic equivalents (MET) whilst in a sitting or reclining posture³, are associated with an increased risk of CVD, independent of physical activity⁴. Being wheelchair-users through necessity means that most individuals with SCI spend long periods of time being sedentary⁵. Therefore, increased CVD risk in individuals with SCI could also be related to high volumes of sedentary time. A systematic review found a lack of interventions targeting sedentary behaviour in individuals with paraplegia⁶, defined as damage to the spinal cord at the first thoracic vertebrae or below, resulting in trunk and lower limb dysfunction⁷. Most intervention studies included in this review involved structured exercise training⁶, which may not target appropriate behaviour change techniques (BCTs) for reducing sedentary behaviour⁸ and fail to promote non-exercise physical activity across the whole day⁹. This review also identified a lack of behaviour change theory to inform intervention design⁶. Theoretically-driven interventions lead to more positive outcomes¹⁰, likely due to the recognition of precursors to behaviour and causal factors of change, which can then be selectively targeted with appropriate BCTs¹¹. Theoretically-driven interventions are, therefore, needed in individuals with SCI.

Co-design is a process in which key stakeholders play an active role in intervention design and development¹², resulting in interventions that are more engaging, satisfying and useful to end-users than traditional researcher-developed interventions¹³. Co-design has been used successfully for sedentary behaviour interventions in office workers¹⁴, older adults¹⁵ and those with severe mental illness¹⁶. Embedding co-design within a suitable behaviour change framework, such as the Behaviour Change Wheel (BCW)¹⁷, has been recognised as a

particularly effective method for intervention development¹⁸. The BCW intervention design process involves an initial behavioural diagnosis using the Capability, Opportunity and Motivation to change Behaviour (COM-B) model and the Theoretical Domains Framework (TDF) to understand the problem and target behaviour¹⁹. This is followed by identification of intervention functions, policy categories, BCTs and delivery modes through which the intervention will operate. A combination of co-production (a similar technique to co-design) and the BCW was employed to develop a sedentary behaviour intervention for stroke survivors, leading to a feasible and replicable intervention²⁰. The use of a combined co-design and BCW approach may, therefore, be an appropriate method for developing a sedentary intervention for individuals with SCI.

Physical activity levels generally increase during inpatient SCI rehabilitation but decline after discharge into the community²¹. This decline is likely due to lack of access to appropriate exercise facilities and the significant challenge of adapting to the home environment after SCI. Although sedentary behaviour improved one year after initial inpatient discharge, levels are still significantly worse compared with non-disabled individuals⁵. Thus, a community-based sedentary behaviour intervention should be designed to support individuals with SCI over the short and longer-term following inpatient rehabilitation.

This study aimed to co-design an intervention, using the BCW framework, to break up and reduce sedentary behaviour in individuals with paraplegia across different stages of the SCI rehabilitation pathway. The objectives were to (a) explore the lived experiences of people with paraplegia regarding barriers and facilitators for breaking up and reducing sedentary behaviour, and (b) identify content and implementation options for the intervention.

Methods

Study design and overview

A qualitative workshop approach was utilised to iteratively co-design the intervention, grounded in behaviour change theory using the BCW framework¹⁷. The co-design process is shown in Figure 1. A total of eight workshops were undertaken separately with participants across three groups: individuals with paraplegia (n = 4 workshops), healthcare professionals (n = 2 workshops), and community caregivers (n = 2 workshops). Workshops were undertaken either online (n = 5 workshops), in-person at Brunel University of London (n = 1 workshop) or at the Royal National Orthopaedic Hospital, London (n = 2 workshops). Activities employed in the workshops included group discussions, writing ideas on post-it notes, visualising ideas using interactive whiteboards, and appraising ideas using Likert rating scales. Figure 2 shows which aspects of the BCW were covered in each workshop. Workshops were facilitated by DLC (MSc; PhD researcher) and supported by AW (PhD), EN (PhD) or DPB (PhD). All researchers had experience in qualitative methods. DLC communicated with participants via email prior to the workshops to organise eligibility screening, consent, and workshop attendance. Introductions were provided by facilitators to explain their role and background at the start of each workshop. The study is reported following the COnsolidated criteria for REporting Qualitative studies²².

Ethical approval was granted from the College of Health, Medicine and Life Sciences Research Ethics Committee, Brunel University of London (47898-NHS-Apr/2024- 50821-2) and the London - Fulham NHS Research Ethics Committee (24/PR/0621). All participants provided informed consent.

Study sample

Individuals with paraplegia (complete or incomplete SCI) who predominantly used a manual wheelchair for mobility were eligible. Healthcare professionals were eligible if they worked in a hospital or clinic providing care or services for individuals with SCI. Community caregivers

provided non-clinical care, services or support to individuals with SCI in the community (friends, family, carers, or employees of relevant organisations/charities), but did not include community healthcare professionals.

Recruitment

Participants with paraplegia were recruited with the aim of achieving a sample that was representative of individuals from across the SCI care pathway after discharge from initial rehabilitation. This involved recruitment from the community via social media, charity organisations and snowballing, in addition to the London SCI Centre, Royal National Orthopaedic Hospital. Healthcare professionals were also recruited from the London SCI Centre, Royal National Orthopaedic Hospital. Community caregivers were recruited from the community through snowballing and charity organisations.

Sample size

Research suggests that 6-10 participants per group across 3-12 workshops is sufficient to consider a diverse range of viewpoints and achieve data saturation, whilst still allowing for in-depth discussion²³. Therefore, a sample size of 6-8 individuals from each participant group was planned for each workshop.

Intervention development

This study followed the three stages of intervention design outlined in the BCW framework (Figure 2).

Stage 1: Understand the behaviour

The problem behaviour, “high sedentary time”, was defined by the research team and discussed with participants at the start of the initial workshops in the context of their experiences around sedentary behaviour. The target behaviour was selected and specified as “reduce and break up sedentary behaviour”.

Identification of what needed to change was achieved by exploring barriers and facilitators to achieving the target behaviour in the initial workshops using the COM-B model as a guide. Barriers and facilitators were mapped to COM-B and the TDF by a researcher after the initial workshops.

Stage 2: Identify intervention options

Potential intervention options to address identified barriers and facilitators were proposed by participants during the initial workshops. In line with the BCW framework, each intervention option was then subsequently mapped to intervention functions and policy categories by the research team.

Stage 3: Identify content and implementation options

Intervention options were mapped to BCTs from the BCT Taxonomy (BCTT)v1²⁴ and modes of delivery by the research team after the initial workshops. This informed the first iteration of intervention concepts. The appropriateness of each concept was appraised using the Acceptability, Practicability, Effectiveness, Affordability, Side-effects/safety and Equity (APEASE) criteria²⁵ in follow-up workshops. The content and/or delivery mode of intervention concepts were then refined through appraisal by the research team in collaboration with PPI members.

Data analysis

Workshops were audio recorded and automatically transcribed using Microsoft Teams (Microsoft Corporation, Redmond, WA, USA). Transcripts were checked for accuracy and participant ID numbers were assigned by a researcher. Data from the initial workshops were analysed by DLC in the context of the BCW using Framework Analysis²⁶. Inductive coding was undertaken using NVivo 12 (Lumivero, Burlington, MA, USA) to identify barriers, facilitators and intervention options. Deductive coding followed to map the inductive codes to domains of the BCW and TDF. Credibility in the data was achieved with approximately 20% of initial workshop transcripts being deductively coded by EN. Based on the APEASE appraisal, the

research team assessed whether each concept was appropriate for inclusion in the intervention via a rating matrix that determined whether intervention concepts fulfilled each individual APEASE criterion.

Peer debriefing was undertaken with researchers not involved in data analysis throughout the study to challenge assumptions and maintain rigour.

Patient and public involvement

Two individuals with paraplegia and a healthcare professional contributed to the development of the workshop guides, recruitment methods and participant information sheet. After the workshops, these public contributors reviewed and provided feedback on the appropriateness of the developed intervention materials.

Findings

Participant characteristics

Twenty-seven participants took part across the workshops. This included 10 participants with paraplegia (PwP; 4 female); see Table 1 for descriptives, 13 healthcare professionals (HCP; 11 female) and four community caregivers (CCG; two female).

Intervention development

Eight workshops were undertaken in total lasting 1 hours 34 minutes on average (range 1-3 hours).

BCW stage 1: Understand the behaviour

Barriers and facilitators to reducing and breaking up sedentary behaviour are categorised and reported according to the COM-B model (Table 2).

Capability

Common capability-related barriers included lack of knowledge about sedentary behaviour (*"There isn't specific guidance on sedentary behaviour [in SCI centres]. So, if there isn't specific guidance, it's hard for people to have knowledge"* [HCP, Physiotherapist]) and fatigue (*"A lot of your time is spent on personal care and just getting the day-to-days done. That can be hugely, hugely physically demanding"* [CCG, Charity worker]). Personal care routines, pain, comorbidities, injury, pressure ulcers, lack of physical function and necessity to transfer to do physical activity were also common barriers. Facilitators included knowledge of pressure relief, feedback on progress, creating schedules around activity and reminders to be active: *"The text message, with the 'get up, do something'. Yeah, it works."* (PwP, T12 incomplete, male).

Opportunity

Frequent opportunity-related barriers were lack of wheelchair-accessible space in and outside of the home (*"Non-adapted space is a barrier"* [PwP, L1 incomplete]), cost and lack of access to equipment to do physical activity or exercise (*"There's not a lot that you can get that is*

complimentary. You know, a lot of this stuff you've got to pay for and it's not cheap" [CCG, Charity worker]), being deterred by family and friends, wheelchairs being inappropriate for physical activity, and geographical inequalities of services or opportunities relating to physical activity and exercise. Facilitators included provision of information and/or opportunities for physical activity and exercise, support from family or friends, and a peer support network: *"There's a thing, isn't there? About community, right? So doing things in a solitary capacity is often quite hard. A lot of barriers to it"* (PwP, T4 complete).

Motivation

Motivation-related barriers included low self-esteem or self-consciousness (*"People don't like being seen in a wheelchair"* [HCP, Physiotherapist]), boredom, being a chore or lack of enjoyment, and low mood. Facilitators included goal setting (*"I like to work towards goals and objectives. The reward itself would be me completing the goal"* [PwP, T11 incomplete]), building habits around activities of daily living (*"If you can make doing something part of your routine a habit, a good habit, then you're more motivated to keep it up"* [PwP, T4 complete]) and rewards.

BCW stage 2: Identify intervention options

Ten different intervention options were identified (Table 3), including (1) receiving feedback on sedentary behaviour and physical activity, to help facilitate feedback on progress: *"[It would] be good to like, keep a log of say yeah, whatever activities you're doing. And having, like, your personal best"* (PwP, L1 incomplete). Reminders to break up sedentary behaviour (2) was commonly proposed to address not thinking about sedentary behaviour (barrier): *"Having some kind of prompt [to get moving] I think would definitely be helpful for him"* (CCG, Family member). Education (3) was suggested to address lack of knowledge about sedentary behaviour (barrier): *"People really need to be made aware of what that [reducing sedentary behaviour] looks like, what that could be, and also and also what the benefits are physiologically and psychologically"* (CCG, Charity worker). To address cost and lack of

access to equipment to do physical activity or exercise (barrier), having physical activity equipment (4) was identified as an option: *“They haven’t got any finances available to purchase any extra [exercise] equipment and that might be what’s needed to be active”* (HCP, Physiotherapist).

A peer support network was suggested as an option to facilitate peer support (5): *“If you’re feeling a little bit demotivated, you know, maybe there’s like a chat or a forum or something”* (PwP, T6 complete). Getting support from family and friends (6) was also suggested to facilitate peer support: *“I think it’s good to involve family and friends. If they’re up for doing it like people have already said, I think it’s a good motivation”* (CCG, Charity Worker). Goal setting (7) came through as an intervention option: *“Could there be like a mentoring or coaching? It could be part of the creating targets. Maybe you can check back?”* (PwP, L1 incomplete). Creating schedules (8) was an option to support planning around activity (facilitator): *“Trying to get a bit of a timetable even into your normal daily living and to and to incorporate the activity in into that”* (CCG, Charity Worker). Signposting to relevant organisations (9) would facilitate the provision of information and/or opportunities for physical activity and exercise: *“If you have a website, you can link it to the local sports groups”* (PwP, T1 incomplete). Gaining rewards for reducing sedentary behaviour (10) could address low confidence or self-esteem (barrier): *“If I could earn a badge for doing a 5-minute exercise on a bad day that might incentivise me for doing it”* (PwP, L1 incomplete).

Identification of intervention functions and policy categories

Six of nine BCW intervention functions were identified as relevant to the intervention options (Table 3). These were Education (n = 3 intervention options were mapped to this function), Enablement (n = 7), Environmental Restructuring (n = 5), Incentivisation (n = 1), Persuasion (n = 2) and Training (n = 1). Six of seven policy categories in the BCW guide were identified as relevant (Table 3), namely Communication/Marketing (n = 4), Environmental/Social Planning (n = 4), Fiscal Measures (n = 1), Guidelines (n = 3), Regulation (n = 2) and Service Provision (n = 4).

BCW stage 3: Identify content and implementation options

Twenty-four BCTs were mapped to the intervention options (Table 3) from the following BCTTv1²⁴ categories: Goals and Planning, Feedback and Monitoring, Social support, Shaping Knowledge, Natural Consequences, Comparison of Behaviour, Associations, Repetition and Substitution, Comparison of Outcomes, Reward and Threat, and Antecedents.

A wearable activity tracker with messaging relevant to wheelchair-users was suggested for providing feedback on physical activity, reminders to break up sedentary behaviour and virtual rewards for breaking up sedentary behaviour and engaging in physical activity. It was proposed that education around sedentary behaviour, signposting to relevant organisations, and information on support from family and friends could be delivered via an educational booklet. Proposed delivery modes for goal setting and creating schedules were a goal-setting worksheet and one-to-one support from a person trained in motivational interviewing. A social messaging app group chat was proposed to facilitate peer support. A pack of activity tools comprising exercise bands and a portable hand cycle was proposed (access to physical activity equipment). Intervention options with overlapping modes of delivery were merged into six intervention components by the research team after the initial workshops and subsequently discussed with participants in follow-up workshops to assess appropriateness and inform refinements.

APEASE assessment

A wearable activity tracker was deemed likely to be effective, with no concerns raised around acceptability, practicability, or safety (Table 4). Concerns were raised around affordability. Equitability was questioned in relation to individuals less proficient with this type of technology but it was felt this could be overcome if participants were provided with guidance.

An educational booklet was deemed likely to be effective. No concerns were raised regarding practicality, affordability or safety. Printed and electronic formats were recommended for ease of access. The term 'sedentary' was not deemed acceptable due to the stigma attached to

wheelchair use: “*Sedentary means you sit on your bum all day. We don’t have a choice. So, I would say ‘inactivity’, ‘improve activity’ or something more positive, rather than leaning on the negative*” (PwP, T1 incomplete). Therefore, the term ‘inactive’ was suggested. It was suggested that positive messaging should be used where possible, (e.g. “break up inactivity”, “do more activity breaks”) rather than limiting sedentary behaviour (e.g. “reduce inactivity”).

Participant feedback on goal setting was generally positive with acceptability, effectiveness, affordability and safety not raising any concerns. Regarding practicability and equity, it was proposed that some participants may require more support than others. This led to the suggestion that motivational support sessions with a trained person could support goal setting through accountability and social support.

Peer support was generally deemed acceptable, practicable, effective, safe and equitable. Most participants noted a widely used app (i.e. WhatsApp) would be unlikely to exclude many participants. However, concerns about the privacy of a group chat were raised in addition to concerns about the effectiveness of such a group as some participants did not feel that they needed peer support. Social comparison of progress with the intervention was deemed less acceptable. Healthcare professionals raised concerns around the risk of undesirable behaviour in the group. To address these concerns, it was agreed that this component of the intervention should be optional, have ground rules for using the chosen app and social comparison should not be advocated.

The activity tools were generally considered to be effective. Some participants suggested tools could be difficult to use due to a lack of knowledge for their use or risk of injury. Therefore, a guidance document was added to this component alongside links to demonstrative videos in the educational booklet.

Discussion

This co-design study has led to the development of a novel intervention targeting sedentary behaviour in individuals with paraplegia. A rigorous co-design approach embedded within the BCW was adopted to maximise the intervention's effectiveness, feasibility and acceptability. The rigorous combined approach and the novelty of the intervention advances knowledge related to developing behavioural interventions and addressing sedentary behaviour in individuals with paraplegia.

The co-design approach employed was acceptable, with high levels of engagement and retention. The opportunity to speak with peers about common problems and potential options to overcome them within the workshops was noted as a positive experience. Co-design may have generated greater participant engagement than traditional researcher-led methods due to a sense of ownership arising from equal partnership^{27,28}. Combining co-design with a workshop-based approach may have increased peer discussion, trust, and openness between participants²⁹, integral to sharing richer and more honest insights²⁹. The co-design workshop approach, therefore, led to a rich dataset and targeted intervention components appropriate for individuals with paraplegia.

The BCW was adopted in this study due to its comprehensive, theory-driven approach to intervention development¹⁷. While the co-design workshops allowed exploration of participant barriers and facilitators, the BCW facilitated a coherent behavioural diagnosis²⁵. As the co-design approach facilitated discussion of preferred intervention options, the BCW allowed the systematic mapping of these²⁵, meaning decision-making can be traced transparently. The APEASE assessment ensured intervention concepts are feasible, acceptable and safe before resources are spent on testing them. The use of behaviour change theory can lead to greater behaviour change in individuals with physical disabilities¹⁰. Therefore, it is likely that the rigorous combined co-design and BCW will result in a more acceptable and effective intervention.

The co-design process led to the need for a multi-component intervention to address a range of unique barriers and facilitators for individuals with paraplegia. This is in line with research demonstrating the superiority of multi-component interventions for reducing sedentary behaviour over single-component interventions in clinical populations³⁰. Additionally, the inclusion of a wrist-worn, wearable activity tracker is consistent with interventions that have reduced sedentary behaviour in non-disabled individuals^{31,32} and clinical populations³⁰. Several BCTs identified in the present study, such as self-monitoring, social support, feedback, and prompts and cues, have been effective in previous sedentary behaviour interventions^{30–32}. Smartphone apps and wrist-worn activity trackers have increased physical activity in individuals with SCI, but these interventions did not target or measure sedentary behaviour^{33,34}. Therefore, previous interventions may not target appropriate BCTs to effectively reduce sedentary behaviour in individuals with SCI⁸. The technology-based component in the current study has been co-designed with a specific focus on sedentary behaviour, which is likely to lead to an acceptable and effective intervention.

Education is included in the present intervention, in line with an intervention co-produced with stroke survivors using the BCW²⁰. This highlights the importance of education around sedentary behaviour in individuals with neurological conditions²⁰. A review found that interventions implementing education were effective for increasing leisure-time physical activity in this population³⁵, however effects on sedentary behaviour have not been examined. Interventions utilising education have shown promise for reducing sedentary behaviour in non-disabled individuals^{36,37}. The present study provides novel findings that an intervention targeting reductions and breaks in sedentary behaviour should include an educational component.

Goal setting is an important intervention component for targeting sedentary behaviour in individuals with neurological conditions, as found in a co-produced intervention in stroke survivors²⁰. Reviews have demonstrated the effectiveness of goal setting for reducing sedentary behaviour in non-disabled individuals in workplace³⁸ and non-workplace settings³⁶,

hence it being likely that goal setting will be effective in the present intervention. Motivational support was included in the present study to aid goal setting and working towards goals. The inclusion of motivational support is backed by a meta-analysis demonstrating that motivational counselling is effective for reducing sedentary behaviour in clinical populations³⁰. In line with findings regarding facilitators for physical activity in individuals with SCI³⁹, peer support was also considered a potential strategy for reducing sedentary behaviour in the present study. Therefore, motivational support and peer support may both be effective for reducing sedentary behaviour in individuals with paraplegia.

Consistent with physical activity research, providing activity tools was identified to help overcome barriers related to affordability and access in individuals with SCI³⁹. Adding objects to the physical environment, such as wearables devices, sit-stand desks and exercise equipment, is an effective intervention strategy to reduce sedentary behaviour in non-disabled individuals^{36,37,40}. However, there is limited evidence evaluating the use of activity tools to enable regular ‘activity breaks’ throughout the day. The inclusion of activity tools is, therefore, a novel component for reducing sedentary behaviour.

Some participants with paraplegia raised concerns with the term “sedentary behaviour” due to the stigma attached around wheelchair use. Instead, these participants suggested referring to “inactivity”, in line with findings in stroke survivors²⁰. This suggests that alternative terminology and/or definitions relating to sedentary behaviour should be developed for individuals with physical disabilities. Some participants with paraplegia also preferred *positive* messaging in relation to the target behaviour (e.g. doing *more* activity, instead of engaging in *less* sedentary behaviour), as was also expressed by stroke survivors²⁰.

Strengths and limitations

Strengths of this study include the use of co-design combined with the BCW to undertake a rigorous and systematic approach to intervention development. The intervention is generalisable to a diverse range of individuals with paraplegia due to the varied sample of

participants at different stages of the SCI healthcare pathway, inclusion of multiple key stakeholders and PPI.

Limitations of the study include the sample size being smaller than planned and comprising only Caucasian participants. A representative view from these participants may, therefore, have not been achieved, potentially limiting generalisability of the intervention. Not all participants were available to participate in both workshops, which is inconsistent with a traditional co-design approach. However, this approach provided the opportunity to understand acceptability of intervention options from individuals who were not involved with developing the initial concepts.

Conclusion

This study reports on the development of a novel intervention targeting sedentary behaviour in individuals with paraplegia. The intervention was co-designed using the BCW, with input from multiple stakeholders, meaning that the developed intervention is likely to be feasible, acceptable and effective for end-users. It is recommended that future interventions are developed utilising a combined approach of participatory methodology and behaviour change theory to optimise acceptability and potential effectiveness. The feasibility, acceptability and effectiveness of the intervention is being evaluated in a further study. This research could inform public health and clinical care guidelines with a focus on sedentary behaviour in individuals with paraplegia.

References

1. Cragg JJ, Noonan VK, Krassioukov A, Borisoff J. Cardiovascular disease and spinal cord injury Results from a national population health survey. *Neurology*. 2013;81(8). <https://doi.org/10.1212/WNL.0b013e3182a1aa68>
2. Gorgey AS, Dudley GA. Skeletal muscle atrophy and increased intramuscular fat after incomplete spinal cord injury. *Spinal Cord*. 2007;45(4). <https://doi.org/10.1038/sj.sc.3101968>
3. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *International Journal of Behavioral Nutrition and Physical Activity*. 2017;14(1). <https://doi.org/10.1186/s12966-017-0525-8>
4. Bailey DP, Hewson DJ, Champion RB, Sayegh SM. Sitting Time and Risk of Cardiovascular Disease and Diabetes: A Systematic Review and Meta-Analysis. *Am J Prev Med*. 2019;57(3):408-416. <https://doi.org/10.1016/J.AMEPRE.2019.04.015>
5. Postma K, Bussmann JBJ, van Diemen T, et al. Physical Activity and Sedentary Behavior From Discharge to 1 Year After Inpatient Rehabilitation in Ambulatory People With Spinal Cord Injury: A Longitudinal Cohort Study. In: *Archives of Physical Medicine and Rehabilitation*. Vol 101. 2020. <https://doi.org/10.1016/j.apmr.2020.06.027>
6. Cooper DL, Warland A, Norris E, Kilbride C, Paddison S, Bailey DP. Effects of interventions on sedentary behaviour and cardiovascular disease biomarkers in individuals with spinal cord injury: a systematic review. *Disabil Rehabil*. 2025. <https://doi.org/10.1080/09638288.2025.2592500>
7. Paddison S, Hexter B. Spinal Cord Injury. In: Lennon S, Ramdharry G, Verheyden G, eds. *Physical Management for Neurological Conditions*. Vol 1. 4th ed. Elsevier Science; 2018:171-203.
8. Martin A, Fitzsimons C, Jepson R, et al. Interventions with potential to reduce sedentary time in adults: Systematic review and meta-analysis. *Br J Sports Med*. 2015;49(16):1056-1063. <https://doi.org/10.1136/bjsports-2014-094524>
9. Manns PJ, Dunstan DW, Owen N, Healy GN. Addressing the nonexercise part of the activity continuum: A more realistic and achievable approach to activity programming for adults with mobility disability? *Phys Ther*. 2012;92(4). <https://doi.org/10.2522/ptj.20110284>
10. Ma JK, Martin Ginis KA. A meta-analysis of physical activity interventions in people with physical disabilities: Content, characteristics, and effects on behaviour. *Psychol Sport Exerc*. 2018;37. <https://doi.org/10.1016/j.psychsport.2018.01.006>
11. Davis R, Campbell R, Hildon Z, Hobbs L, Michie S. Theories of behaviour and behaviour change across the social and behavioural sciences: a scoping review. *Health Psychol Rev*. 2015;9(3). <https://doi.org/10.1080/17437199.2014.941722>
12. Boyd H, McKernon S, Mullin B, Old A. Improving healthcare through the use of co-design. *New Zealand Medical Journal*. 2012;125(1357).

13. Thabrew H, Fleming T, Hetrick S, Merry S. Co-design of eHealth Interventions With Children and Young People. *Front Psychiatry*. 2018;9(OCT). <https://doi.org/10.3389/fpsy.2018.00481>
14. Engelen L, Drayton BA, Young S, et al. Impact and process evaluation of a co-designed “Move More, Sit Less” intervention in a public sector workplace. *Work*. 2019;64(3). <https://doi.org/10.3233/WOR-193020>
15. Blake HT, Davis A, Mellow ML, et al. Co-design of a digital 24-hour time-use intervention with older adults and allied health professionals. *Front Digit Health*. 2025;7:1544489. <https://doi.org/10.3389/FDGH.2025.1544489/BIBTEX>
16. Trott M, Arnautovska U, Korman N, Ritchie G, Siskind D. Sedentary Time Elimination with Periodic activity Snacks (STEPS): protocol for a co-designed feasibility trial in people with severe mental illness. *MedRxiv Preprints*. Preprint posted online July 8, 2025. <https://doi.org/10.1101/2025.07.08.25331057>
17. Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*. 2011;6(1). <https://doi.org/10.1186/1748-5908-6-42>
18. O’Cathain A, Croot L, Sworn K, et al. Taxonomy of approaches to developing interventions to improve health: A systematic methods overview. *Pilot Feasibility Stud*. 2019;5(1). <https://doi.org/10.1186/s40814-019-0425-6>
19. Cane J, O’Connor D, Michie S. Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implementation Science*. 2012;7(1). <https://doi.org/10.1186/1748-5908-7-37>
20. Hall J, Morton S, Hall J, et al. A co-production approach guided by the behaviour change wheel to develop an intervention for reducing sedentary behaviour after stroke. *Pilot Feasibility Stud*. 2020;6(1). <https://doi.org/10.1186/s40814-020-00667-1>
21. van den Berg-Emons RJ, Bussmann JB, Haisma JA, et al. A Prospective Study on Physical Activity Levels After Spinal Cord Injury During Inpatient Rehabilitation and the Year After Discharge. *Arch Phys Med Rehabil*. 2008;89(11). <https://doi.org/10.1016/j.apmr.2008.04.024>
22. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): A 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*. 2007;19(6). <https://doi.org/10.1093/intqhc/mzm042>
23. Krueger RA. *Focus Groups: A Practical Guide for Applied Research*. SAGE Publications; 2015.
24. Michie S, Richardson M, Johnston M, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine*. 2013;46(1). <https://doi.org/10.1007/s12160-013-9486-6>
25. Michie S, Atkins L, West R. *The Behaviour Change Wheel: A Guide to Designing Interventions*.; 2014.
26. Gale NK, Heath G, Cameron E, Rashid S, Redwood S. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med Res Methodol*. 2013;13(1). <https://doi.org/10.1186/1471-2288-13-117>

27. Goodyear-Smith F, Jackson C, Greenhalgh T. Co-design and implementation research: challenges and solutions for ethics committees. *BMC Med Ethics*. 2015;16(1). <https://doi.org/10.1186/s12910-015-0072-2>
28. Jagosh J, MacAulay AC, Pluye P, et al. Uncovering the benefits of participatory research: Implications of a realist review for health research and practice. *Milbank Quarterly*. 2012;90(2). <https://doi.org/10.1111/j.1468-0009.2012.00665.x>
29. Kapiszewski D, Wood EJ. Ethics, Epistemology, and Openness in Research with Human Participants. *Perspectives on Politics*. 2022;20(3). <https://doi.org/10.1017/S1537592720004703>
30. Nieste I, Franssen WMA, Spaas J, Bruckers L, Savelberg HHCM, Eijnde BO. Lifestyle interventions to reduce sedentary behaviour in clinical populations: A systematic review and meta-analysis of different strategies and effects on cardiometabolic health. *Prev Med (Baltim)*. 2021;148. <https://doi.org/10.1016/j.ypmed.2021.106593>
31. Direito A, Carraça E, Rawstorn J, Whittaker R, Maddison R. mHealth Technologies to Influence Physical Activity and Sedentary Behaviors: Behavior Change Techniques, Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Annals of Behavioral Medicine*. 2017;51(2). <https://doi.org/10.1007/s12160-016-9846-0>
32. Stephenson A, McDonough SM, Murphy MH, Nugent CD, Mair JL. Using computer, mobile and wearable technology enhanced interventions to reduce sedentary behaviour: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2017;14(1). <https://doi.org/10.1186/s12966-017-0561-4>
33. Hiremath S V., Amiri AM, Thapa-Chhetry B, et al. Mobile health-based physical activity intervention for individuals with spinal cord injury in the community: A pilot study. *PLoS One*. 2019;14(10). <https://doi.org/10.1371/journal.pone.0223762>
34. Lawrason SVC, Martin Ginis KA. Evaluating the Feasibility, Acceptability, and Engagement of an mHealth Physical Activity Intervention for Adults With Spinal Cord Injury Who Walk: A Randomized Controlled Trial. *J Sport Exerc Psychol*. 2023;45(2). <https://doi.org/10.1123/JSEP.2022-0087>
35. Tomasone JR, Flood SM, Ma JK, et al. Physical activity self-management interventions for adults with spinal cord injury: Part 1—A systematic review of the use and effectiveness of behavior change techniques. *Psychol Sport Exerc*. 2018;37. <https://doi.org/10.1016/j.psychsport.2018.01.012>
36. Curran F, Blake C, Cunningham C, et al. Efficacy, characteristics, behavioural models and behaviour change strategies, of nonworkplace interventions specifically targeting sedentary behaviour; a systematic review and meta-analysis of randomised control trials in healthy ambulatory adults. *PLoS One*. 2021;16(9 September). <https://doi.org/10.1371/journal.pone.0256828>
37. Gardner B, Smith L, Lorencatto F, Hamer M, Biddle SJH. How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults. *Health Psychol Rev*. 2016;10(1). <https://doi.org/10.1080/17437199.2015.1082146>
38. Brierley ML, Chater AM, Smith LR, Bailey DP. The Effectiveness of Sedentary Behaviour Reduction Workplace Interventions on Cardiometabolic Risk Markers: A

Systematic Review. *Sports Medicine*. 2019;49(11). <https://doi.org/10.1007/s40279-019-01168-9>

39. Kehn M, Kroll T. Staying physically active after spinal cord injury: A qualitative exploration of barriers and facilitators to exercise participation. *BMC Public Health*. 2009;9. <https://doi.org/10.1186/1471-2458-9-168>
40. Booth G, Howarth A, Stubbs B, Ussher M. The Effectiveness of Interventions and Intervention Components for Increasing Physical Activity and Reducing Sedentary Behaviour in People With Persistent Musculoskeletal Pain: A Systematic Review and Meta-Analysis. *Journal of Pain*. 2022;23(6). <https://doi.org/10.1016/j.jpain.2021.11.004>

Table 1. Characteristics of individuals with paraplegia (n = 10).

Characteristic		Data is mean $\pm$ SD or n (%)	
Sex	Female		4 (40%)
	Male		6 (60%)
Ethnicity	Caucasian		10 (100%)
Age			50 $\pm$ 10 years
Time since injury			14 $\pm$ 10 years
Lesion level	Thoracic	Total	8 (80%)
		T1	1
		T4	2
		T5	1
		T6	1
		T9	1
		T11	1
		T12	1
	Lumbar	Total	2 (20%)
		L1	2
Completeness	Complete		5 (50%)
	Incomplete		5

Table 2. Barriers and facilitators for reducing and breaking up sedentary behaviour

COM-B construct	COM-B micro-construct	TDF domain	Barrier or facilitator identified (n = number of participants that identified it)	Illustrative quotes
Capability	Physical capability	Skills	Fatigue (barrier) (n = 10)	PwP (T4 complete, male): "The other spinal cord patients I've talked to, people tend to get tired more quickly than you would be if you were not in a wheelchair". PwP (T12 incomplete, male): "I'm deliberately trying not to cram too much in, as I know it makes me tired".
			Personal care routine (barrier) (n = 10)	CCG (Charity worker, male): "When you're newly injured, predominantly a lot of your time is spent on personal care and just getting the day to day done. That can be hugely, hugely physically demanding as well as psychologically". HCP (Physiotherapist, female) "there's less flex in their day, they've got less free time available if they're also a working person to fit that in because, yeah, they're, potentially some of them [have] got longer morning routines".
			Pain (barrier) (n = 7)	PwP (T6 complete, male): "I would say the only thing that's increased my sedentary behaviour is pain". PwP (T4 complete, male): "If you sit still and don't move, then when you do move, it bloody hurts. Simple. You sit there and don't do nothing [anything] all day".
			Comorbidities (barrier) (n = 4)	HCP (Physiotherapist, female): "People have comorbidities and it's an aging population. And so you run into all the same problems with physical activity you do with anybody else". CCG (Charity worker, male): "There might be, you know, underlying health issues that are going on or which might be spinal or non- spinal... your general health can have quite a big impact on your ability to be, you know, sedentary".
			Injury (barrier) (n = 4)	PwP (L1 incomplete, male): "that happens quite frequently, you pick up injuries or stuff happens, you know, that knocks you back".

				PwP (T12 incomplete, male): "When I broke my leg, that's six months in bed".
			Pressure ulcers (barrier) (n = 4)	PwP (L1 incomplete, male): "You know, if you're on bed rest for six months... you know, you had a sore or something" PwP (T4 complete, male): "You could be bedridden for long periods of time [if you got a pressure sore]. We heal a lots more slowly than able-bodied people".
			Lack of physical function (barrier) (n = 4)	PwP (T4 complete, male): "A T12, she will have core muscles and be able to put both arms out in front of her... Whereas me, I'm at 5. If I do that, I'll fall out [of] my wheelchair". CCG (charity worker, male): "The higher your level of injury, then obviously the lower the amount of muscle groups that you've got to use".
			Transfers (barrier) (n = 4)	PwP (T11 incomplete, female) "I used to go the gym before my accident. I think the barrier for me mainly is the amount of transfers that you would have to do". HCP (Physiotherapist, female): "Transfers are more difficult. All of these things, because the first chair that they get from their wheelchair service is rubbish".
	Psychological capability	Knowledge	Lack of knowledge about sedentary behaviour (barrier) (n = 15)	HCP (Physiotherapist, female): "There isn't specific guidance on sedentary behaviour. So there, if there isn't specific guidance, it's hard for people to have knowledge". PwP (T4 complete, male): "I don't think the word sedentary was ever said [during in-patient rehabilitation]".
			Knowledge of pressure relief (facilitator) (n = 6)	CCG (Charity worker, male): "Something that all wheelchair users are told to do is a huge part of their education when they're in hospital is to do pressure relief to make sure every hour or so that they make sure they shift in their chair and lean forward in order to avoid pressure sores". PwP (T4 complete, male): "Part of my routine would then be well, I need to do pressure relief... And therefore, you know, that's exertion"

		Memory, attention, and decision processes	Reminders to be active (facilitator) (n = 5)	PwP (T12 incomplete, male): “The prompts, you know, to the alerts to say. “get moving, get moving”... alerts to say, “come on, keep going. You’re nearly there”, so sort of motivating alerts [would help me be less sedentary]”. CCG (Family member, female): “Definitely that thing of having some kind of prompt I think would definitely be helpful for him [father with paraplegia]”.
			Do not think about sedentary behaviour (barrier) (n = 4)	PwP (T6 complete, male): “I don’t think about it [sedentary behaviour] during the day”. CCG (Charity worker, male): “It’s not really the first thing that’s on their mind, you know, they’ve got other issues to think about”.
		Behavioural regulation	Getting feedback on progress (facilitator) (n = 6)	PwP (L1 incomplete, male): “It’d be good to like, keep a log of say, whatever activities you’re doing. And having like your personal best”. PwP (T6 complete, male): “You can get an app for your phone, so you can actually see what [activities] you’ve done”.
			Creating schedules around activity (facilitator) (n = 6)	CCG (Charity worker, male): “Trying to get a bit of a timetable even into your normal daily living and to and to incorporate the activity in into that”. PwP (L1 incomplete, male): “Yeah, prioritising your schedule to accommodate [for physical activity and sedentary behaviour]”.
Opportunity	Physical opportunity	Environmental context and resources	Provision of information and/or opportunities for physical activity and exercise (facilitator) (n = 12)	HCP (Physiotherapist, female): “They’ll sometimes tap into the charities as well. So they’re going out and about and doing a bit more activity with some of the charities, so again, they’ll start to overcome some of those barriers and see how they can plan things with the help of external sources”. CCG (Charity worker, male): “Wheelpower has probably got the best examples at the moment of showing they they’ve, they’ve got yoga, they’ve got people doing fitness classes and people doing different exercise activities”.

			Lack of wheelchair accessibility in and outside of the home (barrier) (n = 10)	PwP (L1 incomplete, male): "Non-accessible space, I guess. Or non-adapted space [is a barrier]". CCG (Charity worker, male): "When they're discharged from hospital now aren't always going home because their home environments aren't accessible... So it's certainly stuff like that is going to affect their ability to be active".
			Cost and lack of access to equipment to do physical activity or exercise (barrier) (n = 10)	CCG (Charity worker, male): "There's not a lot that you can get that is complimentary. You know, a lot of this stuff now you've got to pay for, and it's not cheap". HCP (Physiotherapist, female): "They haven't got any finances available to purchase any extra equipment and that might be what's needed to be active".
			Wheelchair being inappropriate for physical activity (barrier) (n = 7)	HCP (Physiotherapist, female): "They get given much heavier chairs. Harder to propel and definitely harder to do wheelchair skills in". PwP (T4 complete, male): "At the moment kind of just moving around the house is more difficult in this wheelchair".
			Geographical inequalities of services or opportunities relating to physical activity and exercise (barrier) (n = 5)	PwP (T11 incomplete, female): "The availability. Yeah, just the availability to services really or like the access, you know. Somebody might not live in an area that has an accessible gym". PwP (L1 incomplete, female): "Yeah, there's no accessible gym where I live".
			Support from the workplace (facilitator) (n = 4)	PwP (T4 complete, male): "I adapted my workspace and my work were very good with me in providing that sort of stuff". PwP (T11 incomplete, female): "I think it's the type of job that you do really. I mean, I'm a nurse at a nursing home. That's my job, so I'm constantly moving".
			Excessive planning and inability to be spontaneous (barrier) (n = 3)	PwP (T9 complete, female): "You've got to go through the rigmarole of, you know, what assistance do you need [when going out and about]".

	Social opportunity	Social influences		PwP (T6 complete, male): "The amount of planning you have to do just to go out the door is sometimes unbelievable".
			Support from family or friends (facilitator) (n = 11)	PwP (T4 complete, male): "There's a thing, isn't there? About community, right? So doing things in a solitary capacity is often quite hard. A lot of barriers to it". PwP (L1 incomplete, male): "Having two daughters and a wife, sedentary behaviour is just not allowed, which is good, which is good. They never allow me to wallow myself in self-pity or lay on the sofa".
			Being deterred by family or friends (barrier) (n = 8)	CCG (Family member, female): "I find my mum does a lot for him and maybe that stops him from doing things himself". PwP (T12 incomplete, male): "Family can put barriers up for you. But if you got your own barriers, so it's two fences to get over".
			Peer support network (facilitator) (n = 7)	PwP (T4 complete, male): "Yeah, you know, then again, that community aspect is so encouraging, finding ways for people to connect". CCG (Charity worker, male): "If in some way it can involve contact with others, I think that that's one of the best motivational things out there".
Motivation	Reflective motivation	Beliefs about capabilities	Low self-esteem or self-conscious (barrier) (n = 8)	HCP (Physiotherapist, female): "People don't like being seen in a wheelchair". CCG (Charity worker, male): "Psychological components around motivation and confidence and self-esteem, body image. That that can all contribute to just not finding that 5 minutes [to be active per day]".
		Intentions	Building habits around activities of daily living (facilitator) (n = 7)	PwP (T1 incomplete, male): "Building [activity] into things you've got to do in the house, it gives you a sense of worth, not just for exercise and fitness". PwP (T4 complete, male): "If you can make doing something part of your routine a habit, a good habit. Then you're more motivated to keep it up".

			Boredom, being a chore or lack of enjoyment (barrier) (n = 6)	PwP (L1 incomplete, male): "It [physical activity] being a chore and that might break your motivation cause because it's. It's not enjoyable". PwP (T12 incomplete, male): "They want you in it [standing frame] for like 3 or 4 hours a day. What can you do, stood? What can you do? It's boring".
		Goals	Goal setting (facilitator) (n = 8)	PwP (L1 incomplete, male): "Realistic goals I guess, that's the one I mean. Because you know, if you start out thinking "Why am I not at the top of the Mount Everest, yet?"". PwP (T11 incomplete, female): "When I say objectives and goals, I mean personally I like to work towards goals and objectives".
		Reinforcement	Rewards (facilitator) (n = 5)	PwP (L1 incomplete, female): "If I could earn a badge for doing a 5-minute exercise on a bad day that might incentivise me for doing it". PwP (T11 incomplete, female): "The reward itself would be me completing the goal".
	Automatic motivation	Emotions	Low mood (barrier) (n = 3)	PwP (L1 incomplete, female): "I have good days and bad days and on a good day I'm fine. I can do stuff. It's not a problem, but on a bad day it can vary between not getting out of bed or getting out of bed but not going out the house". HCP (Physiotherapist, female): "The biggest barrier to general levels of physical activity is how you're thinking and feeling and that comes down to psychology".

CCG, Community Caregiver; COM-B, Capability, Opportunity and Motivation to change Behaviour; HCP, Healthcare Professional; PwP,

Participant with Paraplegia; TDF, Theoretical Domains Framework.

Table 3. Intervention options mapped to the COM-B, TDF and BCW constructs

COM-B micro-construct	TDF domain	Barrier / facilitator being targeted	What needs to change	Proposed intervention option	Intervention function	Policy category	Behaviour change techniques	Delivery mode
Psychological capability	Behavioural regulation	Getting feedback on progress (facilitator)	Individual becomes aware of their sedentary behaviour and physical activity	Feedback on sedentary behaviour and physical activity	Enablement, Education	Guidelines, Communication/marketing	2.2: Feedback on behaviour	Wearable tracker, health and fitness app, feedback from an individual trained in motivational support
	Knowledge	Lack of knowledge about sedentary behaviour (barrier)					2.3: Self-monitoring of behaviour 12.5: Adding objects to the environment	
Psychological capability	Memory, attention and decision processes	Reminders to be active (facilitator)	Individuals are regularly prompted to break up their sedentary behaviour	Reminders to break up sedentary behaviour	Environmental restructuring, Enablement	Environmental/social planning	7.1: Prompts/Cues	Notifications or prompts via a wearable activity tracker or app
		Do not think about sedentary behaviour (barrier)						
Automatic motivation	Emotions	Low mood (barrier)	Individuals are given a reward for breaking up and/or reducing sedentary behaviour and increasing physical activity	Rewards for reducing and/or breaking up sedentary behaviour and engaging in physical activity	Incentivisation, persuasion	Fiscal measures	10.1: Material incentive (behaviour)	Streaks, badges, praise via an app or wearable activity tracker and praise from an individual trained in motivational support
Reflective motivation	Beliefs about capabilities	Low self-esteem or self-conscious (barrier)					10.2: Material reward (behaviour)	
	Reinforcement	Rewards (facilitator)					10.7: Self-incentive 10.9: Self-reward	
Psychological capability	Knowledge	Lack of knowledge about sedentary behaviour (barrier)	Individuals being made aware of what sedentary behaviour is and how to reduce	Education around sedentary behaviour	Education, Persuasion	Guidelines, Communication/marketing	4.1: Instruction on how to perform a behaviour	Online and physical educational booklet, role models, integrate into

		Knowledge of pressure relief (facilitator)	and/or break it up, drawing similarities to existing pressure relief advice				5.1: Information about health consequences	existing pressure relief advice, integrate into activities of daily living
Physical capability	Skills	Fatigue (barrier)	Individuals being made aware of the physical, psychological and emotional benefits of reducing and breaking up sedentary behaviour				5.6: Information about emotional consequences	
		Pain (barrier)					8.2: Behaviour substitution	
		Comorbidities (barrier)					8.3: Habit formation	
Reflective motivation	Intentions	Building habits around activities of daily living (facilitator)					9.1: Credible source	
Social opportunity	Social influences	Support from family or friends (facilitator)	Family members, carers and/or friends providing support to reduce sedentary behaviour	Support from family and friends to reduce sedentary behaviour	Environmental restructuring	Environmental/social planning	3.1: Social support (unspecified)	Within educational resource, suggesting that participants do physical activity with family and friends, explaining the benefits of doing so and including examples of how to involve them
Reflective motivation	Intentions	Boredom, being a chore and lack of enjoyment (barrier)					3.2: Social support (practical) 12.2: Restructuring the social environment	
Physical opportunity	Environmental context and resources	Provision of information and/or opportunities for physical activity and exercise (facilitator)	Being signposted to national and local charities, organisations and websites that provide equipment, information and/or opportunities relating to physical activity or exercise	Signposting to charities, organisations and websites	Enablement, Education	Service provision, Communication/marketing	3.1: Social support (unspecified)	Virtual or physical resource containing a list of links to and contact details of relevant charities, organisations and websites
		Lack of wheelchair accessibility in and outside of the home (barrier)						
		Cost and lack of access to equipment to do						

		physical activity or exercise (barrier)						
Reflective motivation	Goals	Goal setting (facilitator)	Individuals setting and monitoring personalised goals related to sedentary behaviour and physical activity	Goal setting	Training, Enablement	Regulation, Guidelines, Communication/ Marketing	1.1: Goal setting (behaviour) 1.4: Action planning 1.5: Review behaviour goals	Self-selection and review of goals with support from an individual trained in motivational support, goal setting and monitoring using a wearable activity tracker and/or app
Psychological capability	Behavioural regulation	Creating schedules around activity (facilitator)	Creating schedules to reduce sedentary behaviour and increase physical activity that fit around fatigue, pain, personal care and other commitments	Scheduling	Environmental restructuring, Enablement	Service provision, Regulation	1.1: Goal setting (behaviour) 1.4: Action planning 1.8: Behavioural contract 1.9: Commitment	Physical or virtual calendar, support with creating schedules from an individual trained in motivational support
Physical capability	Skills	Pain (barrier)						
		Fatigue (barrier)						
		Personal care routine (barrier)						
		Pressure ulcers (barrier)						
		Comorbidities (barrier)						
Reflective motivation	Goals	Goal setting (facilitator)						
	Intentions	Building habits around activities of daily living (facilitator)						

Social opportunity	Social influences	Peer support network (facilitator)	Having access to a network of peers with a spinal cord injury to share experiences of participating in the programme, ideas to reduce sedentary behaviour and opportunities to do physical activity	Peer support network	Enablement, Environmental restructuring	Service provision, Environmental/ social planning	3.1: Social support (unspecified)	A group chat in a messaging app
Reflective motivation	Intentions	Boredom, being a chore or lack of enjoyment (barrier)					3.2: Social support (practical)	
Physical capability	Skills	Transfers (barrier)	Individuals being provided access to activity tools to use at home, regardless of geographical location	Providing access to activity tools	Enablement, Environmental restructuring	Service provision, Environmental/ social planning	12.1: Restructuring the physical environment	An equipment pack including exercise bands and a portable hand cycle to use at home
Physical opportunity	Environmental context and resources	Cost and lack of access to equipment to do physical activity or exercise (barrier)					12.5: Adding objects to the environment	
		Geographical inequalities of services or opportunities relating to physical activity and exercise (barrier)						
		Excessive planning and inability to be spontaneous (barrier)						
		Wheelchair being inappropriate for activity(barrier)						

Data are presented in order of COM-B micro-construct to provide broad categories of barriers and facilitators, TDF to provide context as to the nature of each barrier or facilitator, followed by the specific barrier or facilitator in question. The intervention option that targets each barrier/facilitator and how it maps to each BCW construct is provided in sequential order in the subsequent columns. COM-B, Capability, Opportunity and Motivation to change Behaviour; TDF, Theoretical Domains Framework.

Table 4. Assessment of intervention components using the APEASE criteria

Intervention component	Acceptability	Practicability	Effectiveness	Affordability	Safety/side effects	Equity	Comments
Wearable activity tracker	✓	✓	✓	X	✓	✓	It may not be affordable if participants were required to purchase wearable trackers with wheelchair mode. Concerns around the technological proficiency required are overcome by researchers providing guidance.
Educational booklet	✓	✓	✓	✓	✓	✓	Concerns around accessibility of the format are overcome by offering both printed and electronic versions. Concerns around acceptability of terminology overcome by using inclusive and positive wording in the materials.
Goal setting	✓	✓	✓	✓	✓	✓	Concerns around lack of support with creating and working towards goals are overcome by the inclusion of motivational support.
Motivational support	✓	✓	✓	✓	✓	✓	Concerns around the practicability of access to a medically qualified individual are overcome through delivery by an individual with suitable motivational support training.
Peer support group	X	✓	✓	✓	X	✓	Concerns around acceptability of social comparison are overcome by not sharing activity data between participants. Concerns around privacy are overcome by this component being optional and setting clear ground rules.
Activity tools	✓	✓	✓	✓	✓	✓	Safety concerns around injury are overcome by providing guidance for using the tools safely.

Figures

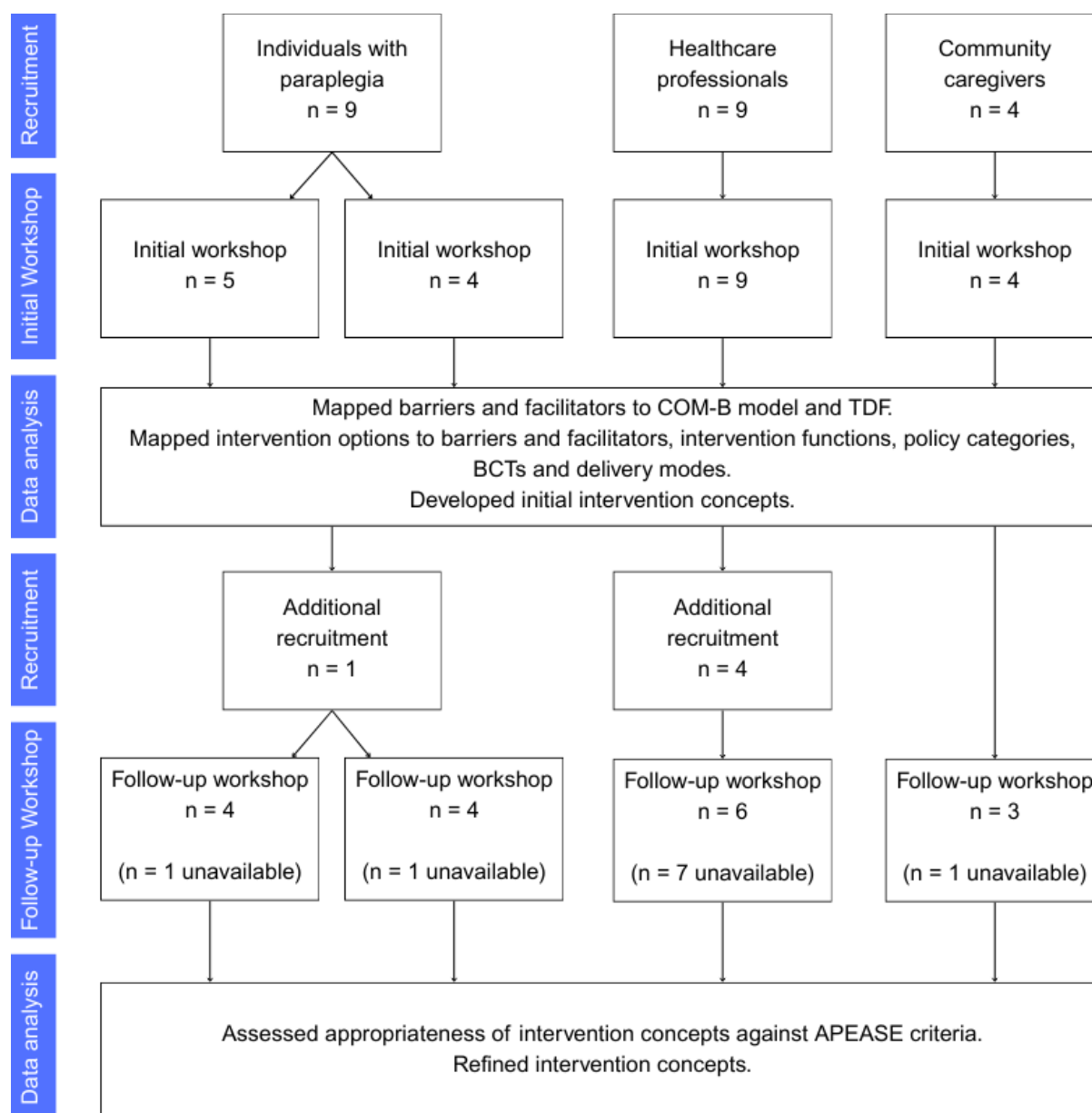


Figure 1. The study co-design process. APEASE, Acceptability, Practicability, Effectiveness, Affordability, Side-effects/safety, Equity; BCT, Behaviour Change Technique; COM-B, Capability, Opportunity and Motivation to change Behaviour; TDF, Theoretical Domains Framework.

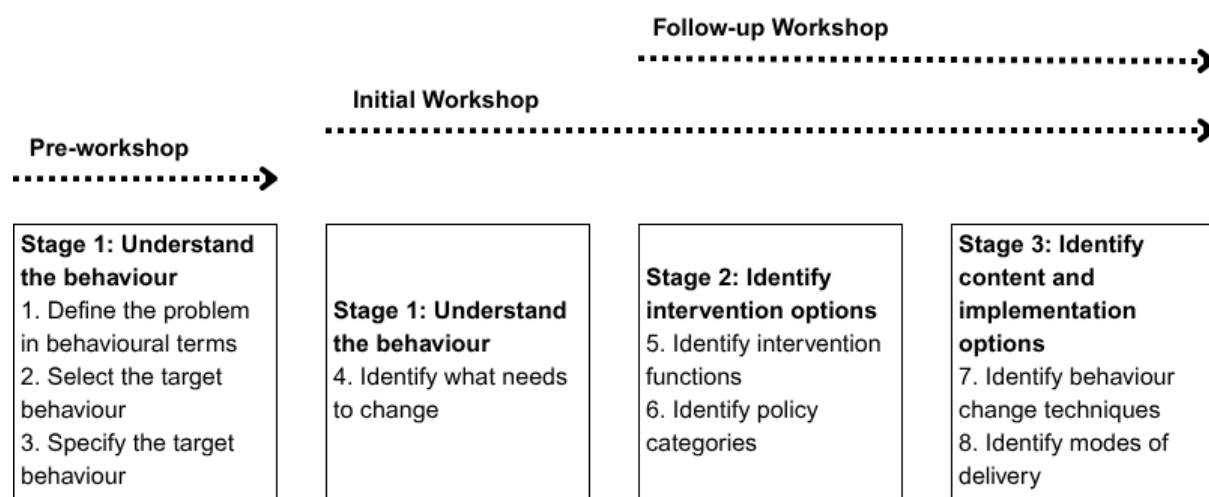


Figure 2. Data collection flowchart detailing the Behaviour Change Wheel stages addressed at each stage of the study