BMJ Open

Feasibility study of high-intensity interval training to reduce cardiometabolic disease risks in individuals with acute spinal cord injury

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To cite: Maher JL, Whitmarsh C, Smith P, *et al*. Feasibility study of high-intensity interval training to reduce cardiometabolic disease risks in individuals with acute spinal cord injury. *BMJ Open* 2023;**13**:e068507. doi:10.1136/bmjopen-2022-068507

► Prepublication history for this paper is available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2022-068507).

Received 21 September 2022
Accepted 21 December 2022

Check for updates

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ABSTRACT

Introduction Individuals ageing with spinal cord injury (SCI) experience an accelerated trajectory of diseases and disorders, such as cardiovascular disease and diabetes, that resemble those experienced with ageing alone. Currently, an evidence-based approach toward managing this problem does not exist and therefore the purpose of this study is to determine the feasibility of conducting a high-intensity exercise intervention in individuals with acute (<6 months postinjury) SCI to improve cardiometabolic health.

Methods and analysis We will conduct a single-centre, two parallel-arm, randomised feasibility study of a high-intensity interval training (HIIT) intervention in individuals with acute SCI. We will enrol 40 individuals (20 intervention, 20 control) with acute SCI attending inpatient rehabilitation at Salisbury District Hospital. Participants will be randomly allocated to the intervention group (HIIT) or control group for 18 weeks. Both groups will participate in standard care throughout the duration of the study. The HIIT group only will also perform supervised HIIT exercise on an arm cycle ergometer three times per week. Over the course of the intervention, most participants will be discharged from the hospital, and at this time, an arm cycle ergometer will be installed in their home and the intervention will transition into outpatient care. We will assess cardiorespiratory fitness, glycaemic control, lipid profile and body habitus as well as qualitative assessments of acceptability at weeks 0, 9 and 18 with the primary outcome being the feasibility of a full Randomised Controlled Trial (RCT).

Ethics and dissemination This study will inform a longer-term, definitive, multicentre RCT to establish the impact of this exercise intervention in maintaining the cardiometabolic health of patients during the acute phase following SCI. Results will be disseminated in different formats including peer-reviewed journal articles, conference presentations and internet media, to a wide audience including clinicians, researchers and individuals with SCI.

Trial registration number ISRCTN57514022.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study addresses the need to prevent decay in cardiometabolic health and physical function in the acute phase following a spinal cord injury (SCI) and stands to have a substantial impact on the health and well-being of these patients.
⇒ The intervention is simple, inexpensive and low-risk for the patient population.
⇒ Quantitative and qualitative approaches will be used for a comprehensive assessment of outcome measures.
⇒ Study recruitment and procedures will only occur in one SCI unit and therefore findings may not be generalisable to all acute care units.
⇒ Complications such as infection and depression occur at a high rate in acute SCI and can confound outcome measures or exclude patients from participating at all.

INTRODUCTION

Spinal cord injury (SCI) is typically caused by a traumatic event with wide ranging physiological and psychological consequences. SCI results in disruption to normal sensory, motor and/or autonomic function and ultimately social well-being, depending on the level and completeness of lesion. Living with SCI requires substantial healthcare resources and can place a significant economic burden on patients, their families and the healthcare system.[1] With recent improvements in technology and medical and rehabilitative care, individuals with SCI are now living significantly longer postinjury.[2 3] Consequently, these individuals ageing with SCI experience an accelerated trajectory of diseases and disorders that resemble those experienced with ageing alone.[4]

Premature mortality in individuals with SCI is up to three times higher than in the non-injured population.[5] The primary physical cause for morbidity and mortality in both men and women with SCI is the development of cardiovascular disease (CVD).[6] One of the main risk factors for CVD is obesity,

which occurs earlier and is the most prevalent secondary medical complication following SCI,[4] affecting >60% of the SCI population.[7 8] Immediately following SCI, there are significant changes in body composition and metabolic profile. Caudal to the level of injury there is rapid and substantial skeletal muscle atrophy, primarily in the lower limbs.[9] Body composition significantly deteriorates during the first 6 months following SCI with total lean body mass decreasing by ~9.5%, coupled with a substantial loss of lower limb lean mass within 1 year following injury.[10] Increases in adipose tissue mass and reductions in skeletal muscle mass after injury are major determinants of chronic cardiometabolic disorders,[11] including insulin resistance[12] and atherogenic lipid profiles.[13] These comorbidities are strongly associated with macrovascular disease (ie, coronary artery disease, peripheral vascular disease, stroke)[13] and diabetes.[12] In fact, approximately 50% of individuals with chronic SCI are found to have frank diabetes, despite having normal fasting glucose levels.[12]

Current management of SCI focusses on functional rehabilitation and does not include any form of programme to minimise cardiometabolic degeneration. Indeed, an effective evidence-based approach to the management of this problem does not currently exist. In view of the high prevalence, health consequences and costs associated with SCI, a greater emphasis needs to be placed on identifying early and effective therapeutic interventions. Early exercise intervention during the acute phase of inpatient rehabilitation following SCI (ie, <6 months postinjury) may serve as a preventative measure to reduce the burden of long-term chronic diseases on both the patient and healthcare services. Indeed, the acute rehabilitation environment represents the ideal timing and location to embed healthy lifestyle behaviours, including upper-body exercise conditioning. However, high-quality clinical trials are required to establish the efficacy of exercise interventions for maintaining a healthier and more favourable body composition and, primarily, for maintaining the metabolic health of patients during the acute phase following SCI.

Interventions using moderate-intensity exercise have induced some favourable adaptations in untrained individuals with chronic SCI (improved functional capacity (ie, cardiorespiratory fitness and peak power output) and a range of health-related quality of life (HR-QoL) measures).[14 15] However, it is likely that higher-intensity exercise may be necessary to achieve broader benefits for metabolic regulation and cardiovascular health. Given these findings, we propose incorporating high-intensity interval training (HIIT) as a worthwhile alternative to moderate-intensity exercise in this population.[16]

A growing body of evidence suggests that upper-body HIIT may yield more favourable effects on a range of cardiometabolic indices compared with moderate-intensity continuous training (MICT).[17–22] HIIT involves alternating periods of high-intensity activity, at or below maximal aerobic capacity, interspersed with light recovery exercise intervals.[23] This allows untrained or deconditioned individuals to complete a substantial amount of work at a relatively high intensity with less local muscular fatigue. Users can achieve greater physiological stimulus and associated adaptations, thus producing larger benefits for cardiorespiratory fitness and other metabolic regulatory processes, ultimately leading to greater prevention and/or amelioration of cardiometabolic risks.[23] Notably, HIIT is also reported to be more enjoyable than MICT, which may inspire greater long-term adherence to exercise programmes.[24]

In a 2017 systematic review on exercise and SCI, only 22 studies on interventions in acute SCI met the inclusion criteria, and of these, only four were graded level one or two studies.[25] The Grading of Recommendations, Assessment, Development and Evaluation assessments exposed a 'lack of high-quality, consistent, precise, or direct evidence' for outcomes related to cardiorespiratory fitness and cardiovascular risk, among others. The authors concluded that 'despite tremendous ethical and practical challenges of conducting high-quality, adequately powered studies in people with acute SCI, Randomised Controlled Trials (RCTs) are needed to control for deteriorations in fitness and health that typically occur in the first month's post injury'. Nonetheless, there have been no new level 1 or 2 clinical trials added to the evidence base in the last 8 years and still none using HIIT. Therefore, the aim of this study is to formally evaluate the feasibility of undertaking a randomised control trial of early intervention upper-body HIIT in individuals with acute SCI. Quantitative and qualitative feasibility assessments will be undertaken to inform the decision to proceed with an RCT to assess the effect of this intervention.

The primary objectives of the feasibility study are as follows:

1. To assess the participant recruitment rate.
2. To assess retention and adherence to the study.
3. To examine, qualitatively, the acceptability of the intervention, study design and outcome measures as well as participants' and clinicians' experiences with the intervention.

The secondary objectives are:

1. To use the qualitative component of the study to refine the intervention to ensure that it is acceptable to both patients and clinicians, and feasible to deliver within the NHS SCI centres.
2. To evaluate and refine quantitative data collection procedures and outcome measures.
3. To develop training resources for intervention delivery (eg, short video and handbook) for use in a subsequent multicentre RCT.

METHODS AND ANALYSIS

Study design

This is a single-centre two parallel-arm, randomised feasibility study of a high-intensity exercise intervention in individuals with acute SCI (<6 months postinjury), which

will provide high-quality evidence to inform the design of a definitive multicentre RCT. This study was approved by the North West—Liverpool Central Research Ethics Committee (REC reference number 21/NW/0029; approved 4 March 2021) and registered on the International Standard Randomised Controlled Trial Number registry on 15 May 2021. Amendments to the documents submitted in the original REC application will be submitted using a valid notice of amendment to REC and to the trial sponsor. The study will be conducted in accordance with ethical principles for studies involving human participants set out in the Declaration of Helsinki.

Patient and public involvement

The research team conducted a patient and public involvement (PPI) event with five patients (injury level: C5-T6; length of injury: 4–12 months; time in unit: 3–9 months) currently admitted to inpatient rehabilitation at The Duke of Cornwall Spinal Treatment Centre at Salisbury District Hospital (SDH). We obtained feedback on the relevance and expected feasibility of the intervention and outcome measures to be assessed in this study. We will host further PPI events with patients currently admitted as inpatients at the SCI unit throughout the research process. Through these events we will recruit SCI stakeholders to be involved in the study through active participation in the research, serving as a member of the Trial Steering Committee (TSC), Trial Management Group (TMG) and engagement in dissemination plans.

Recruitment and consent process

The study and all recruitment will be conducted at SDH. Participants will be identified by trained clinical staff, based on the stated inclusion and exclusion criteria (see below). Recruitment occurs when the patient is medically stable (ie, clinical opinion) and considered ready to engage in structured exercise and receive information about the study. Interested and eligible participants will be approached by a study team member and asked to provide written informed consent.

Study population/sample size

We aim to recruit 40 individuals (20 intervention, 20 control) with acute SCI attending inpatient rehabilitation at SDH. As this is a feasibility study, the sample size was estimated to ensure that the feasibility parameters, which will be used to plan the full trial, can be measured with sufficient precision based on the width of the CIs. It is not based on the estimated sample required to identify a statistically significant difference between the two groups. It is anticipated that the retention rate is likely to be 75%, therefore, when 40 participants are recruited, an exact two-sided 95% CI will have a width 0.29.

Eligibility criteria

Inclusion criteria

The following inclusion criteria define people who are eligible for the trial:

1. Males and females.
2. Aged ≥18 years.
3. SCI <6 months (any level injury/AIS grade assuming the remaining criteria are met).
4. Sufficient upper extremity motor function to complete arm crank ergometry exercise.
5. Use a wheelchair as their main method of mobility (>75% of the time).

Exclusion criteria:

Individuals presenting with any of the following will be excluded from participating in the trial:

1. Unresolved pressure ulcer.
2. Upper limb pain that limits exercise.
3. Recurrent acute infection or illness.
4. Previous (<4 weeks) myocardial infarction or cardiac surgery.
5. Intubation or tracheostomy.
6. Individuals who self-report significant upper extremity pain.
7. Women who become pregnant will be advised to notify clinical staff, and on notification, will be withdrawn from the trial.
8. Cognitive impairment deemed a risk by the healthcare team for participation in the trial (eg, diagnosis of neurodegenerative disease).
9. Unable to understand explanations and/or provide informed consent.
10. Any condition and/or behaviour that would pose undue personal risk or introduce bias into the trial.

Randomisation

After baseline assessments, participants will be randomly allocated (1:1) to an HIIT intervention or a standard care control group (CON) using a block randomisation plan. Randomisation will be performed using a web-based platform (sealed envelope, London, UK). Blinding is not achievable in this intervention study, and therefore neither participants nor research staff will be blinded. figure 1 details the trial flow chart.

Assessments

The trial comprises three assessment visits across the 18-week intervention (weeks 0, 9 and 18). All measurement visits will take place at SDH. Participants will be given the option to perform their final outpatient assessments at the University of Bath if that is more convenient. Table 1 lists outcome measures, sampling times and participant time burden for testing. Detailed methods are listed below.

Qualitative feasibility evaluation: We will evaluate patient participants and clinician's perceived acceptability of the intervention with:

1. Online open-ended survey. All patient participants will be offered the opportunity to respond to an open-ended survey at weeks 6 and 16. The survey will explore the acceptability, adaptation, efficacy and integration and expansion potential of the intervention.
2. The survey will be followed up (weeks 9 and 18) with an in-depth semi-structured interview with a purposive

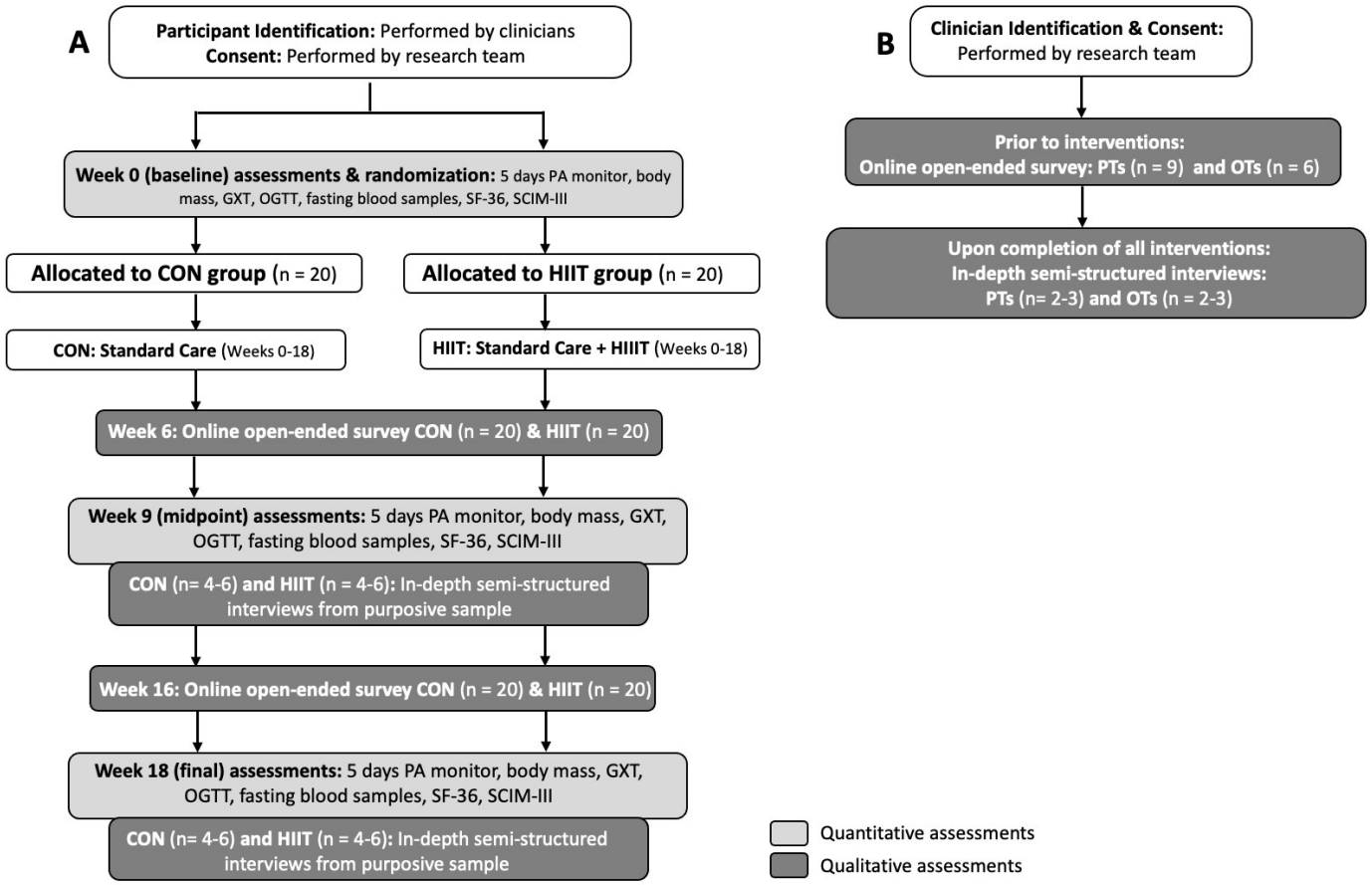

Figure 1 (A–B) Trial flow chart. CON group, control group; GXT, graded exercise test; HIIT, high-intensity interval training; OGTT, oral glucose tolerance test; PA, physical activity; SCIM-III, Spinal Cord Independence Measure-III; SF-36, Short Form 3; PTs, Physiotherapists; OTs, Occupational Therapists.

selection of 4–6 participants in the intervention group and 4–6 participants in the CON group to assess the way in which the delivery of the intervention is perceived, and any changes or adaptation required in this process.

Physiotherapists (n=9) and occupational therapists (n=6) involved in delivering standard care to patients' rehabilitation in the hospital setting will be offered the opportunity to respond to an open-ended survey to explore current care pathways. Following completion of all interventions, in depth interviews will also be conducted with a purposively selected group of 4–6 clinicians to identify areas that will need to be adapted or changed to implement the intervention in practice in a future trial or rollout of the intervention.

Basic injury information and patient demographics will be obtained electronically at the start of the study using Research Electronic Data Capture (REDCap) electronic data capture tools hosted at the University of Bath. REDCap (Harris *et al*[26] 2009) is a secure, web-based software platform designed to support data capture for research studies, providing: (1) an intuitive interface for validated data capture; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to common statistical packages and (4) procedures for data integration and interoperability with external sources.

Wheelchair Users Shoulder Pain Index: Completed weekly to assess changes in shoulder pain during the study.

Free-living energy expenditure: All participants will be asked to wear a wrist-mounted physical activity monitor (GENEA Active) for 5 days at weeks 0,8 and 17 to estimate free-living physical activity energy expenditure. This device has been previously validated in this population.[27]

Health-related Outcomes: We will assess a range of health-related outcome measures for feasibility of data collection and for the purpose of designing the full RCT. The following will be measured by research staff:

1. *Body mass* will be obtained using a calibrated wheelchair scale in which we will weigh the participant and their chair together, then the chair alone and subtract the difference. Height will be measured with participants in the supine position. Body mass index will be calculated by dividing body mass (kg) by height (m) squared. Waist circumference (cm) will be measured at the narrowest point between the lowest rib and iliac crest, and hip circumference (cm) will be measured at the widest point of the gluteal using a tape measure.
2. *Cardiorespiratory fitness* will be assessed as peak oxygen consumption (VO_{2peak}) as determined by a graded ex-

Table 1 Overview of outcome measures, data collection, data entry, sampling times and participant time burdens for testing

Variable	Measure/data source	RedCap database entry		Study timeline (weeks)					Time (min)
		Patient	Research team	0	6	9	16	18	
Basic injury information and demographics	Questionnaire	X		X					10
Shoulder pain	Wheelchair Users Shoulder Pain Index (WUSPI)*	X		X	X	X	X	X	5
Free-living exergy expenditure	Wrist-mounted physical activity monitor (GENEA Active) for 5 days		X	X		X		X	Worn 24 hours/day
Acceptability of the intervention: patient participants	Online open-ended survey	X			X		X		30
	Semi-structured interview		X			X		X	60
Acceptability of the intervention: clinicians	Online open-ended survey	X		X					30
	Semi-structured interview		X					X	60
Body mass	Calibrated wheelchair scale		X	X		X		X	5
Cardiorespiratory fitness	Peak oxygen consumption (VO_{2peak})		X	X		X		X	40
Insulin resistance/ sensitivity	Oral glucose tolerance test (OGTT)		X	X		X		X	130
CVD risk	Triglycerides, total cholesterol, NEFA, HDL-C, LDL-C		X	X		X		X	
Quality of life	Medical Outcome Study SF-36—wheelchair adapted	X		X		X		X	10
Independence	Spinal Cord Independence Measure-III (SCIM-III)	X		X		X		X	20

*All participants will complete the WUSPI weekly throughout the study period.
CVD, cardiovascular disease; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; REDCap, Research Electronic Data Capture; SF-36, Short Form-36.

ercise test (GXT) using an electronically braked arm-cycle ergometer (Angio, Lode BV, Groningen, Netherlands). Exercise termination will be consistent with the ACSM Guidelines for Exercise Testing and Prescription.[28] A ramp-based protocol will begin with a 2 min warm-up at 10 watt before increasing by 1 watt every 6 s. The test will continue until volitional exhaustion manifested as either a non-verbal communication of the desire to stop or the inability to maintain cadence at 60±5 rpm. Heart rate (HR) and oxygen consumption will be recorded continuously from baseline through recovery. HR will be measured, and expiratory gases will be collected and analysed with a portable metabolic analyser (Cosmed K5, Rome, Italy). A rating of perceived exertion (RPE) on a 6–20 scale will be recorded at the end of each stage. VO_{2peak} will be defined as the highest 15-breath rolling average achieved during the maximal exercise test. In all maximal exercise tests, two or more of the following criteria will be used to clarify achievement of VO_{2peak}: HR within 10 beats of age-predicted maximum, respiratory exchange ratio ≥1.15, RPE ≥19 and/or volitional exhaustion. Peak HR (HR_{peak}) will be used to prescribe the intensity of the HIIT intervals.

3. *Insulin resistance, insulin sensitivity and CVD risk* will be assessed via a 2-hour oral glucose tolerance test. Participants will be prepared under antiseptic conditions with an antecubital venous catheter to undergo a 2-hour oral glucose tolerance test using a 75 g glucose load (Rapilose OGTT Solution, Galen Limited, Craigavon, UK) ingested over 5 min. Blood samples will be collected at 0, 30, 60, 90, 120 into separate tubes containing clot lysis activator and sodium fluoride. Plasma glucose and serum insulin will be measured via commercially available spectrophotometric assays and ELISA. Serial measurements of glucose and insulin responses at baseline and in response to the OGTT (0, 30, 60, 90, 120 min) will be converted into simple summary statistics: insulin resistance will be estimated by the Homeostasis Model Assessment of Insulin Resistance, whole body insulin sensitivity will be estimated using the Matsuda index and glucose and insulin area under the curve will be calculated using the standard trapezoid method. Fasting blood samples will also be used to determine relevant blood lipid concentrations (eg, triglycerides, total cholesterol, non-esterified fatty acid, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol).

The above outcome measures will be entered into REDCap by a member of the research team. An independent colleague will cross-check entry in 10% of cases to prevent data entry errors.

Quality of life and independence questionnaires will be administered electronically.

1. *Short Form 36*, a measure to assess HR-QoL concepts which represent basic human values and are relevant to an individual's functional status and well-being.
2. *Spinal Cord Independence Measure-III*, a 19-item questionnaire assessing domains of self-care, respiration and sphincter management and mobility.

Intervention

All patients receive standard care, which includes three small group physiotherapy sessions per week, incorporating general rehabilitation exercises aimed at gaining efficiency in functional independence. Both HIIT and CON groups will continue to participate in standard care throughout the duration of their inpatient rehabilitation stay.

HIIT sessions

In addition to standard care physiotherapy sessions, participants randomised to the intervention group will perform an additional 3 days per week of HIIT exercise on an arm cycle ergometer (Monark Compact Rehab 871e) that is adapted for use with a wheelchair. Participants will be asked to perform 10×60 s intervals at 80%–90% peak HR (HR_{peak}). To account for changes in fitness and ensure progression, the intensity will be reassessed and increased to maintain the desired HR response. Each exercise session will include a 5 min warm-up and cool-down at ~5 watts, with 60 s recovery intervals at ~5 watts, resulting in a total exercise time of 30 min. During each exercise training session participants will be asked to wear a chest-worn HR monitor (Wahoo Tcker X; Wahoo Fitness, Atlanta, Georgia, USA) and view their HR response in real time using a smartphone application.

Participants will attend the exercise laboratory three times per week and the HIIT programme will be supervised and delivered by a clinical exercise physiologist (CEP). For the first 4 weeks, the CEP will provide physical assistance with setting up for the exercise as well as encouragement and verbal guidance regarding exercise performance. At the start of week 5, participants will begin to transition to autonomous training, in preparation for discharge to outpatient care, with the goal of being fully autonomous by the end of week 6–8. During the transition period, the CEP will provide guidance only when participants struggle to remember proper set-up or execution. When guidance is provided, it will be as minimal as possible. Most participants will be discharged home from the rehabilitation unit over the course of the 18-week intervention and therefore the intervention will begin at SDH (ie, inpatient care) and end in participants' homes (ie, outpatient care).

At discharge, participants will receive an arm ergometer (the same model they have used during inpatient care) for continuing the intervention in their own homes for the remainder of the 18-week intervention. Participants will be asked to continue to perform three sessions per week and avoid performing two exercise training sessions on the same or consecutive days. Participants will be asked to continue wearing a chest-worn HR monitor (Wahoo Tcker X) for every training session to monitor adherence and compliance. Participants will be given training logs to be completed after each session and will receive a weekly phone call from study staff to confirm compliance. The CON group will be asked to continue with their regular activities.

Withdrawal criteria

Recruited patients will be informed that they can freely withdraw their informed consent and discontinue participation at any time during the trial. Participants may be withdrawn from the trial if there is a change in their eligibility. During baseline testing, contraindications and limitations to exercise may be identified during the GXT[29] which will result in participants being withdrawn on safety grounds. All withdrawals will be discussed with the participants clinician.

Outcome measures

Study outcomes will be assessed using a mixed methods approach. The primary outcomes are surrounding feasibility. Quantitative data will be analysed to determine (1) the proportion of eligible patients who accept the invitation to participate in the research study and (2) the proportion of patients who complete the study, and for those in the intervention group, the proportion of intervention sessions completed. A qualitative approach will be used to determine acceptability of the study through thematic analysis of open-ended surveys and interview data for patient and staff groups.

Secondary outcomes surround identifying facilitators and barriers relevant to the design of a subsequent RCT. Completion rates for each outcome measure will be evaluated to determine if an outcome should be removed. Clinicians will evaluate acceptability of training resources (short instructional video(s) and handbook) for intervention delivery. Qualitatively, we will use comments and feedback from thematic analysis to refine the intervention to ensure acceptability from both a patient and clinician perspective.

Statistical analyses

As this is a feasibility study, p values will not be reported as formal inferential statistical analyses will not be conducted. Feasibility measures, namely, the proportion of participants' eligible, consented, randomised, retained and completing follow-up will be reported with 95% CIs calculated using the Exact Binomial Method. A Consolidated Standards of Reporting Trials diagram will be produced. For those in the intervention group, the proportion of participants adequately completing the intervention (as per our a priori success criteria) and the average number of exercise sessions completed will be reported.

Outcome data will be analysed using intention-to-treat principles, using all randomised patients with available outcome data. The distributional properties of the continuous variables will be examined by plots. Participant baseline characteristics and outcomes will be summarised using descriptive measures: mean (SD) or median (IQR) for continuous variables; number (per cent, %) for categorical variables; and absolute and per cent change for longitudinal data and will be tabulated by treatment allocation.

Qualitative analyses

The open ended surveys and the interview data for both patient and staff groups will be analysed using thematic analysis.[29] This will enable us to develop an understanding of the acceptability, feasibility and perceived benefits of the intervention and standard care for both patients and staff. Comparison of the intervention and usual care will facilitate an understanding of the way in which any future trial may change usual care, and any adaptations that may be required to implement the intervention in other settings in a full trial.

Study management and safety

The University of Bath, as Sponsor, will monitor and conduct random audits on a selection of studies in its clinical research portfolio. Monitoring and auditing will be conducted in accordance with the Department of Health Research Governance Framework for Health and Social Care (April 2005), and in accordance with the Sponsor's monitoring and audit policies and procedures.

The TMG will consist of the chief and principal investigators, those individuals involved in running the study and a patient representative. The TMG will meet monthly to monitor progress and supervise the trial to ensure that it is conducted in accordance with the approved protocol and principles of good clinical practice. The TSC will act as a wider trial advisory committee and will meet at the mid-point and end of the study. The TSC will monitor data, adverse events, serious adverse events and make recommendations to the TMG regarding safety and ethical issues. They will advise on issues that have arisen during the feasibility trial and will identify how to best move things forward to the full RCT. The committee will be comprised of independent experts in the field: SCI nurse, therapist,[2] clinicians from other spinal treatment centres, an expert trial statistician and[2] patient representatives. The TSC will be led by an independent Chairperson who is not directly involved with the study other than as a member of the TSC and is not part of the same institution as any of the applicants or coapplicants. Day-to-day management of the study rests with the chief investigator.

The trial has been designed to reduce risks and burdens as much as possible, with the further aim of reducing potential risks and burdens further by strict adherence to best practice. All the above will be explained to the potential participant verbally and in the participant information sheet to ensure that they are fully informed before giving consent.

Data management and confidentiality

The University of Bath will act as the Data Controller for data generated by this trial. Identifying data (name, date of birth, contact details and next of kin details) will be kept by the University of Bath. This data will be stored in a password-protected Excel spreadsheet on a desktop computer stored in a locked room. This data will be deleted following the final study contact during the follow-up. Signed consent forms will be stored in a locked cupboard and kept for 10 years to evidence the consent process.

Deidentified study data, coded with a unique study ID assigned to each participant, will be kept by the University of Bath. The study-specific folder can only be accessed by the research team. Hard copies of trial data will be stored in a locked cupboard at the University of Bath. Study data will be kept for 10 years in line with the University of Bath research data policy (see: http://www.bath.ac.uk/research/data/policy/index.html). Participant's samples will be stored in accordance with the Human Tissue Act 2004.

All protocol contributors named in this document will have access to the final trial dataset. Requests for access by other researchers within the Department for Health at the University of Bath will be approved by the TMG.

Post-trial care

Participants will be provided with feedback on some of their test results after completing the trial period. This will include cardiorespiratory fitness/physical capacity and fasting blood data, with reference to population norms and recommended guidelines.

Dissemination

The data arising from this trial will be submitted for publication and presented at conferences (International Spinal Cord Society, American Spinal Injury Association, American College of Sports Medicine) and meetings. People will be notified of the outcomes of the trial via the Spinal Injuries Association and related charities and support groups.

DISCUSSION

Evidence obtained in this study may serve to strengthen the way that healthcare is delivered during inpatient rehabilitation following SCI. Despite the wealth of evidence on the beneficial effects of exercise, including the recent publication of exercise guidelines for people living with SCI,[30] the current care pathway lacks any formal therapeutic exercise conditioning component. Early exercise interventions may represent a safe, self-administered, cost-effective approach to prevent disease and enhance independence for individuals with SCI, thereby decreasing costs related to healthcare usage in subsequent years after

discharge from inpatient rehabilitation. The results of this study will have broader implications for the management and prevention of disease in a range of inpatient populations with limited mobility such as amputees, lower-limb trauma, hip and knee osteoarthritis and joint replacement, stroke, and ageing.

Contributors JLM and JB conceived the study and obtained grant funding. JLM, CW, PS, HT, AF and JB participated in the design of the protocol. JLM drafted the protocol and wrote the protocol manuscript. All authors critically reviewed and approved the study protocol and associated manuscript.

Funding This work was supported by The National Institute of Health Research, grant number (NIHR 201591).

Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; peer-reviewed for ethical and funding approval prior to submission.

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