Psychology of Sport & Exercise 67 (2023) 102408

Contents lists available at ScienceDirect

Psychology of Sport & Exercise

journal homepage: www.elsevier.com/locate/psychsport

Review

Effects of behaviour change interventions on physical activity in people with spinal cord injury: A systematic review and meta-analysis

Paul K. Watson [a,*], Aitthanatt C. Eitivipart [b], Glen M. Davis [a], Mohit Arora [c,d], James W. Middleton [c,d], Camila Quel De Oliveira [e]

[a] *Sydney School of Health Sciences, Faulty of Medicine and Health, The University of Sydney, NSW, Australia*
[b] *Accessibility and Assistive Technology Research Team, Assistive Technology and Medical Devices Research Centre, National Science and Technology Development Agency, Pathum Thani, Thailand*
[c] *John Walsh Centre for Rehabilitation Research, The Kolling Institute, Northern Sydney Local Health District, St Leonards, NSW, Australia*
[d] *Translational Research Collective, The University of Sydney, Sydney, NSW, Australia*
[e] *Discipline of Physiotherapy, Graduate School of Health, University of Technology Sydney, NSW, Australia*

A R T I C L E I N F O

Keywords:
Spinal cord injury
Exercise
Physical activity
Behaviour
Behaviour change theory
Behaviour change techniques

A B S T R A C T

Objectives: This review investigated the effectiveness of behaviour-change interventions to improve physical activity (PA) participation in individuals with a spinal cord injury. Additionally, the review sought to analyse the change in PA behaviour that might be expected by utilising behaviour change in PA interventions and what specific intervention characteristics, application of behaviour change theories, and behaviour change techniques are most efficacious.
Methods: The protocol was prospectively registered on PROSPERO: CRD42021252744, and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines were followed in this review. Eight databases were comprehensively searched using a well-defined strategy developed in collaboration with an academic liaison librarian. Randomised, non-randomised controlled, and non-controlled studies were included in this review; however, controlled and non-controlled studies were analysed separately. Studies were included if participants were older than 16 years and had an SCI of any cause, level or severity, regardless of the time since injury. The behaviour change technique taxonomy version 1 was used to code the intervention characteristics for behaviour modification. The combined effects across studies were pooled in a meta-analysis, and the risk of bias was assessed using the Cochrane Risk of Bias 2 tool.
Results: The search retrieved 10,155 titles and abstracts. After duplicate removal and screening against the eligibility criteria, 23 studies were included. The overall effect estimate of the change in PA participation in the controlled trials post-intervention was medium ($d = 0.50$, 95% CI = 0.31–0.70) in favour of behaviour-targeted interventions. The mean difference in PA volume between pre- and post-intervention was an increase of 22 minutes per week (95% CI = 5.96–38.90). Interventions that provided practical support ($d = 0.81$, 95% CI = 0.46–1.16), which were individualised ($d = 0.62$, 95% CI = 0.34–0.90) and that utilised monitoring ($d = 0.59$, 95% CI = 0.34–0.83) had a greater effect on change to PA than those that were group-based and did not utilise those specific techniques.
Conclusions: Interventions that target behaviour change to increase PA in people with SCI appear effective. Utilising behaviour change frameworks and specific behaviour change techniques augments PA uptake and levels, and interventions aimed at improving PA in people with SCI should incorporate a behaviour modification component. More research is needed on the isolated effect of intervention structure parameters and specific behaviour change techniques.

Spinal cord injury (SCI) results in physical disability requiring significant adjustments to lifestyle and daily functioning for the individual (Krause, 1998). Whether caused by disease or trauma, some of the adverse secondary medical sequelae include pressure sores, autonomic

* Corresponding author.
E-mail address: pwat2143@uni.sydney.edu.au (P.K. Watson).

https://doi.org/10.1016/j.psychsport.2023.102408
Received 12 September 2022; Received in revised form 21 February 2023; Accepted 1 March 2023
Available online 5 March 2023

dysfunction, urinary tract infections, hypotension, joint contractures, thermal dysregulation, and decreased bone mass (Johnson et al., 1998). In addition, muscle paralysis and reliance on mobility devices emanate reduced energy expenditure, lower muscular strength and endurance, and diminished cardiovascular fitness (Sezer, 2015). These characteristics predispose individuals to an increased risk of cardiovascular and metabolic diseases such as obesity, dyslipidaemia and diabetes, thus reducing life expectancy, quality of life and well-being (Sezer, 2015).

Regular physical activity (PA) improves the health of major body systems (Anderson & Durstine, 2019; Stewart et al., 2005), reduces the likelihood of chronic disease, improves symptoms of existing illnesses, and positively affects psychological health (Haskell et al., 2007; Mikkelsen et al., 2017; Nystoriak & Bhatnagar, 2018). In the SCI population, exercise reduces cardiovascular disease risk, improves cardiometabolic health and fitness, improves both subjective and objective quality of life, and influences functional independence and social relationships (Kawanishi & Greguol, 2013; Tomasone et al., 2013; van der Scheer et al., 2017).

Approximately 50% of the SCI population are sedentary, and those that engage in PA often do not meet the recommended levels to prevent cardiometabolic diseases (Eitivipart et al., 2021; Rocchi et al., 2017; Watson et al., 2022). The literature shows that the reasons for low PA engagement vary but are most commonly associated with biological impairments, emotional distress, an altered body-self relationship, a lack of knowledge on where and how to physically engage, absences of time, energy and motivation, issues with access, the cost of programs or facilities, and a lack of appropriate resources and mobility (Fekete & Rauch, 2012; Williams et al., 2014).

A behaviour change theory synthesises knowledge of the mechanisms of action (the mediators) and the moderators of change, as well as the assumptions of human behaviour and its influences (Davis et al., 2015). These theories and behaviour change techniques (BCTs) (i.e., practical actions and strategies that facilitate change) provide a valuable framework for understanding PA engagement. Simultaneously, they present a promising way to improve PA participation in the SCI population by offering strategies to drive change toward a desired end-state (Samdal et al., 2017). Evidence suggests that interventions based on behaviour theory effectively change population-level behaviour, address barriers, and promote PA uptake (Brand & Cheval, 2019). However, integrating numerous theories and BCTs is usually needed for more significant changes in PA outcomes (Hagger & Weed, 2019).

Physical activity behaviour change interventions have been proven effective in previous meta-analyses of the general population (Rhodes et al., 2021). Analyses of the effect of the intervention constructs (such as the method and format of delivery, and the degree to which a behaviour change theory was utilised) have highlighted the significant influence that moderators such as behaviour theory application and method of intervention delivery have on the overall effect. A recent thematic analysis (Williams et al., 2017) identified five essential components of interventions aimed at increasing PA participation in people with physical disabilities: (i) the method of delivery of the intervention, (ii) the person delivering it, (iii) information provided to participants on PA and their degree of access to services, (iv) what behavioural strategies were taught to target commencement and maintenance of PA, and (v) adequate social support (especially from health professionals).

Physical activity behaviour change in the SCI population has been examined in varying detail. A systematic review (Wilroy & Knowlden, 2016) of theory-based PA interventions for people with SCI provided a descriptive analysis of the influence of intervention design and implementation, and the overall effectiveness of interventions. A subsequent review (Tomasone et al., 2018) found that 32 out of a possible 93 BCTs have been utilised (a total of 222 times) in SCI studies to increase PA participation. Described using a narrative synthesis approach, their effectiveness in improving PA outcomes was evident, and authors suggested that theory use, intervention dose, mode of delivery, the provider of the intervention, and individual tailoring of the intervention may be essential to consider for optimising intervention outcomes. However, the heterogeneity between studies, specifically concerning study design or how techniques were implemented, highlighted the need for improved reporting (at the trial level) and further consideration of the practical application of techniques used within interventions.

In 2018, a meta-analysis (Ma & Martin Ginis, 2018) reported the effect of randomised controlled trials (RCTs) that tested PA behaviour change interventions among people with a physical disability. Within the study, the investigators conducted a sub-group analysis of RCTs ($n = 4$) involving people with only SCI and reported a positive medium-sized effect ($g = 0.54$) favouring groups that received a behaviour-change intervention. The authors also examined whether studies that utilised behaviour change theories produced bigger effect sizes than studies that were atheoretical, if the intensity of intervention was related to the degree of behaviour change, how the characteristics of the interventions (such as the method of delivery and dose) were related to effect size, and whether specific BCTs produced larger effect sizes than others. The results indicated that PA-enhancing interventions were effective for increasing PA in adults with physical disabilities, and that a higher quantity of BCT use does not translate to greater effects of interventions. Instead, some BCTs, such as self-monitoring, problem-solving, and instruction on performing a behaviour, showed a greater impact on outcomes than others. Their analysis, however, was applied to all studies included (which included populations such as multiple sclerosis, osteoarthritis and other physical disabilities), not the SCI population specifically. Since these findings, more than twice the amount of SCI-specific RCTs that have utilised behaviour change interventions to target PA behaviour has been conducted and reported.

Understanding the effectiveness of behaviour change strategies and how best they can be applied to the individual and entwined with PA interventions is crucial to reduce the intrinsic and extrinsic barriers that individuals with SCI face when engaging in PA. Hence, this review sought to examine the effectiveness of behaviour-change interventions on PA behaviour for people with SCI and to understand the importance and effect of study constructs on the intervention outcomes.

1. Methods

This systematic review followed the framework of the Cochrane Handbook for Systematic Reviews of Interventions (Higgins, 2022) and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher et al., 2015). The protocol for this review was prospectively registered on PROSPERO on June 3 2021, and there was no deviation from it (ID: CRD42021252744): https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=252744.

1.1. Literature search strategy

Eight databases were searched from inception: Medline, EMBASE, Web of Science, SCOPUS, SPORTDiscuss, CINAHL, PsycINFO and COCHRANE Central. Included studies were limited to English, as prior research has shown no differences in retrieved studies when studies written in different languages were included (Morrison et al., 2012). The current review intended to include unpublished studies and studies classified as 'grey' literature to minimise publication bias. The search strategy, which included using a university-developed Systematic Review Toolkit for the 'grey' literature search, was developed in collaboration with an Academic Liaison Librarian. It included a combination of words, phrases and Medical Subject Headings comprising three domains: (1) Spinal Cord Injury: 'spinal cord injury' OR 'spinal cord' OR 'spinal cord ischemia' OR 'paraplegia' OR 'tetraplegia' OR 'quadriplegia' (2) Physical Activity: 'exercise*' OR 'sport' OR 'fitness' OR 'physical activity' OR 'leisure activity' (3) Behaviour: 'behav*' OR 'habit' OR 'learn*' '*model*' OR '*theory*' (see Supplement A for a sample search). In addition, backward citation searching and screening, and analysis of the reference lists for each study that met inclusion criteria were conducted to ensure that all published studies of interest were considered for inclusion. The initial search was completed in September 2021, and an updated search was conducted in July 2022.

2. Inclusion/exclusion criteria

2.1. Study design

Randomised, non-randomised controlled, and non-controlled studies were included. The low number of randomised controlled studies in the SCI and PA behaviour domain (Ma & Martin Ginis., 2018; Tomasone et al., 2018) warranted inclusion of non-randomised controlled studies for this specific and rare population outcome (Higgins, 2022). Non-controlled studies have been presented separately herein and were not included in the meta-analysis.

2.2. Participants

Studies were included if they had participants with an SCI of a minimum age of 16 years, irrespective of cause, level and severity of the injury, and time since injury. Studies with mixed populations were only included if data for participants with an SCI could be extracted separately.

2.3. Interventions and comparisons

Studies that utilised a therapeutic intervention, which included a behaviour change component, aimed at increasing PA levels were included. Non-controlled studies were included if a behaviour change theory or utilised BCTs informed the experimental intervention.

Control groups were either a PA-only intervention, usual care, or an intervention used explicitly in a control-group capacity.

2.4. Outcomes

Studies that investigated a quantifiable change in PA participation levels were included. Levels of PA could be measured in various ways, including surveys and questionnaires, logbooks, or diaries. Frequency (how many times per day/week/month/year a person engages in PA) and duration (the amount of time of PA a person performs within a single session) were the two exercise parameters of interest. The time points included in the analysis were baseline, the immediate end of the intervention, and a follow-up assessment (if it was performed). The longest follow-up assessment was chosen, where more than one follow-up assessment was conducted.

2.5. Exclusion

Studies that contained mixed populations (and when SCI-specific information could not be separately extracted) and studies where interventions did not include a behavioural modification approach to increase PA levels were excluded.

3. Data screening

Search results were downloaded into Endnote version 20, wherein duplicate citations were removed. The remaining studies were uploaded to COVIDENCE Systematic Review Software (Veritas Health Innovation, Melbourne, Australia, https://www.covidence.org/) (Babineau, 2014), where more duplicates were removed. COVIDENCE is a primary screening and data extraction tool for Cochrane authors conducting standard intervention reviews (Higgins, 2022). Two review authors (PW and ACE) independently screened the relevant titles. Abstracts were then screened against the inclusion and exclusion criteria. Finally, full-text screening was undertaken for those articles whose abstracts had met inclusion criteria. Disagreement between authors was resolved via discussion, and where resolution could not be achieved, a third author (CQO) was consulted.

3.1. Data extraction

Two review authors (PW and ACE) extracted information independently and compared the results. Any disagreement in the extracted data was resolved by consultation with a third review author (CQO).

The authors of the included studies were contacted via e-mail when missing or incomplete information was identified or to obtain relevant information on SCI participants in studies with mixed populations. Contact was attempted twice (two weeks apart) and considered missing data if the authors were unresponsive. Studies with missing data were excluded from this review.

Extracted data included: author, year of publication, country of study origin, and study design. Participant information extracted included: the number of participants, number of participant dropouts, average participant age and time since injury, number of males and females, number of persons diagnosed with paraplegia and tetraplegia, completeness of injury, and the PA levels of participants at baseline, which was usually an inclusion criterion in each trial. Intervention characteristics extracted included: duration, setting, mode of delivery, format (whether the intervention was individual or group-based), provider of intervention, intensity, intervention description (including frequency, intensity, time, type, and materials provided), the outcome used, outcome measurement time points and the quantitative results of the intervention. Intervention intensity was measured using a scale incorporating the intervention's duration, frequency of contact, type of contact and reach (Hendrie et al., 2013). The intervention characteristics' coding was aligned with previously used methods (Ma & Martin Ginis, 2018).

4. Identification and coding of behaviour change theory and techniques

A behaviour change technique was defined as an observable and replicable component related to behaviour change and is the mechanism of the change (Michie et al., 2013). When previous reviews (Ma & Martin Ginis, 2018; Tomasone et al., 2018) had classified the behaviour change theories or BCTs utilised in the studies included in this review, their classification was reported. Two authors (PW and ACE) completed the Behaviour Change Technique Taxonomy version 1 (BCTTv1) (Michie et al., 2013) Online Training Program (https://www.bct-taxonomy.com) before extraction of BCT data. The BCT coding and behaviour change theory extraction were done independently by two authors (PW and ACE). Results were compared, and definition or classification discrepancies were discussed to reach a consensus. A third review author (CQO) was consulted when an agreement was not reached.

4.1. Study appraisal

The revised Cochrane Risk of Bias 2 tool (RoB 2) (Sterne et al., 2019) was used to assess bias in the included controlled studies. This tool classifies the outcomes of each study as 'low' or 'high' risk of bias or as having 'some concerns' of bias within five domains: (i) randomisation process, (ii) deviations from the intended intervention (including blinding), (iii) missing outcome data, (iv) the measurement of outcomes, and (v) the selection of the results the authors choose to report. The RoB 2 assessment is specific to a single outcome for an included study; in our case: change to PA. The Cochrane RoB 2 assessment was performed by two authors (PW and ACE) separately. Any difference in results was discussed to reconcile, and a third review author (CQO) was contacted for unresolvable differences. No risk of bias assessment of the non-controlled studies was undertaken as they were not included in the meta-analysis and carry inherent bias due to the lack of a control group.

Visual examination of a funnel plot was conducted, and an Egger's test was performed to identify any publication bias.

4.2. Data analysis

A meta-analysis was conducted using the Statistical Package for the Social Sciences (SPSS) v29 for the controlled studies. The random-effects method (Der Simonian & Laird, 1986) was used in effect size analyses to allow for variation of intervention methods and population characteristics between included studies (Dettori et al., 2022). The effect size was calculated using Cohen's d and interpreted as small (0.2–0.4), medium (0.5–0.7) or large (0.8 or greater) (Cohen, 2013). In addition, the mean difference (MD) of change to PA in minutes per week (min/wk) was calculated to provide the magnitude of change. Previous work in this field (Ma & Martin Ginis, 2018) utilised the Cochrane Q statistic to identify heterogeneous data and thus warrant moderator analysis (analysis of study constructs such as dose, mode, and format). However, except for whether a behavioural theory was used and the intensity of its application, no Q statistic was reported as significant. Nonetheless, the authors conducted the analysis as was mentioned *a priori*. In this study, we reported the Q statistic for the effect size and the I^2 index for the mean difference (min/week) for all subgroups. I^2 interpretation was based on the Cochrane guidelines (Higgins, 2022).

Total PA values were used in the analysis. Where there were no values for total PA, moderate or vigorous-intensity PA were used. The recommended Cochrane method (Higgins, 2022) combined reported results into a single value where studies reported no total but moderate and vigorous PA. When studies did not report standard deviation (SD), the methods suggested by Higgins (2022) to compute SD based on p-values, t-test statistics and the standard error were used.

The effect size was calculated for the effect of the intervention on the change in PA at the post-intervention assessment. For studies that reported a follow-up measure, sensitivity analysis was performed to examine the difference between the post-intervention and follow-up effects. Effect size analysis between studies was conducted for intervention constructs, including the intervention's length, provider, format, and mode. Length of intervention was categorised as (i) less than 3 months, (ii) 3–6 months, and (iii) greater than 6 months. Intervention providers were categorised as (i) physical activity specialists (physiotherapists, physiologists, exercise specialists, exercise counsellors), (ii) researchers, or (iii) other. When a study did not explicitly mention the intervention provider, we classified the provider as the researcher. The format was categorised as (i) individual, (ii) group, or (iii) individual and group. Mode of delivery was categorised as (i) in-person, (ii) technology (telephone, online meeting, e-mail), or (iii) in-person and technology. The setting was classified as either (i) home-based, (ii) clinic/gym-based, or (iii) both home and clinic/gym based. Study effect sizes and intervention intensity, and study effect sizes and the duration of intervention were analysed in separate regression models.

Effect size analysis between studies was also conducted on the intensity of behaviour change theory use and the use of BCTs. Studies were classified as using behaviour change theories in five different ways and were informed by previous literature (Ma & Martin Ginis, 2018; Painter et al., 2008): (i) no mention of theory, (ii) informed by theory (when a theory was mentioned, but no application of it was apparent), (iii) applied theory (when some of the theoretical constructs were applied in the intervention), (iv) testing theory (when most of the theoretical constructs were applied in the intervention), and (v) building or creating theory (when a theory was revised or expanded upon). Effect sizes were regressed on the number of BCTs used in each study to examine the relationship between the quantity of BCT use and effect size. Where a BCT had been used in three or more studies, methods used previously (Ma & Martin Ginis, 2018; Olander et al., 2013) were used to calculate the effect size of interventions that did and did not utilise the BCT, and significant difference between these effect sizes was calculated using the Q statistic (Borstein et al., 2009).

5. Results

5.1. Search results

A PRISMA flowchart for reporting of included studies is presented in Figure 1. Twenty-three studies were included based on the inclusion criteria. Supplement B provides a list of all included studies, and Supplement C lists excluded studies (with reasons for exclusion) after the full-text screening.

5.2. Study characteristics

Of the 23 studies, 14 were controlled, and nine were non-controlled. All controlled studies were randomised except one (Hisham et al., 2022). Two sets of two articles were reports of the same study. Rocchi et al. (2021) was an implementation evaluation of Chemtob et al. (2019) and did not generate any additional outcomes of interest for this review. Thus, these two articles were summarised and analysed as one study in this review. Thomas et al. (2011) and Wise et al. (2009) reported on thr same study but focused on the effect of different components of the intervention (interaction with a healthcare professional and home physical activity programs, respectively), and both reported the same PA outcomes. Thus, these two articles were summarised and analysed as one study in this review.

Twenty-one of the 23 studies were funded be either a foundation or research institute, one was supported by an Australian state government commission (de Oliveira et al., 2016), and one (Bassett & Martin Ginis., 2011) was not funded. Included studies were conducted in Canada (n = 11), the USA (n = 7), the Netherlands (n = 2), Australia and New Zealand (n = 1), England (n = 1) and Malaysia (n = 1).

5.3. Participant characteristics

The total number of participants in the included studies was 994, with an average of 48 participants per study (range 12–168). Dropouts ranged from 0 to 48 participants per study; of the 994 participants, 208 (21%) dropped out across all studies. Males comprised 63% of participants across all studies (range 5–96 per study), and females ranged from 4 to 72 per study. The participants' mean age was 47 (±4.4) years. The time since injury ranged from 0.5 to 23.3 years, with an average of 14.4 (±5.6) years. Across all included studies, there were 32% more people with paraplegia than quadriplegia, and three studies (Hisham et al., 2022; Latimer-Cheung et al., 2013; Nightingale et al., 2018) had samples composed only of individuals with paraplegia. Eleven studies reported the completeness of the SCI. Individuals with sensorimotor 'complete' injuries (International Standards for Neurological Classification of Spinal Cord Injuries (ISNCSCI) (Maynard et al., 1997) A) were 24% more common than individuals with 'incomplete' injuries (ISNCSCI B, C and D).

Fourteen studies contained an inclusion criterion for the current volume of PA undertaken by participants before the onset of the study, the most common being a requirement that participants had to be completely sedentary before enrolment (n = 8).

5.4. Intervention characteristics

Interventions ranged from four weeks to eight months in duration, and four studies (de Oliveira et al., 2016; Kooijmans et al., 2017; Nooijen et al., 2016; Thomas et al., 2011) included follow-up assessments that ranged from three to seven months post-intervention. All the interventions were delivered solely in the participant's home (n = 13) or at both the participant's home and a research clinic or gym (n = 8).

Interventions were administered either in person (n = 3), using technology such as a telephone or a virtual meeting (n = 8), or by a combination of both (n = 10). Interventions were individualised most of the time (n = 14), with two interventions (Arbour-Nicitopoulos et al.,

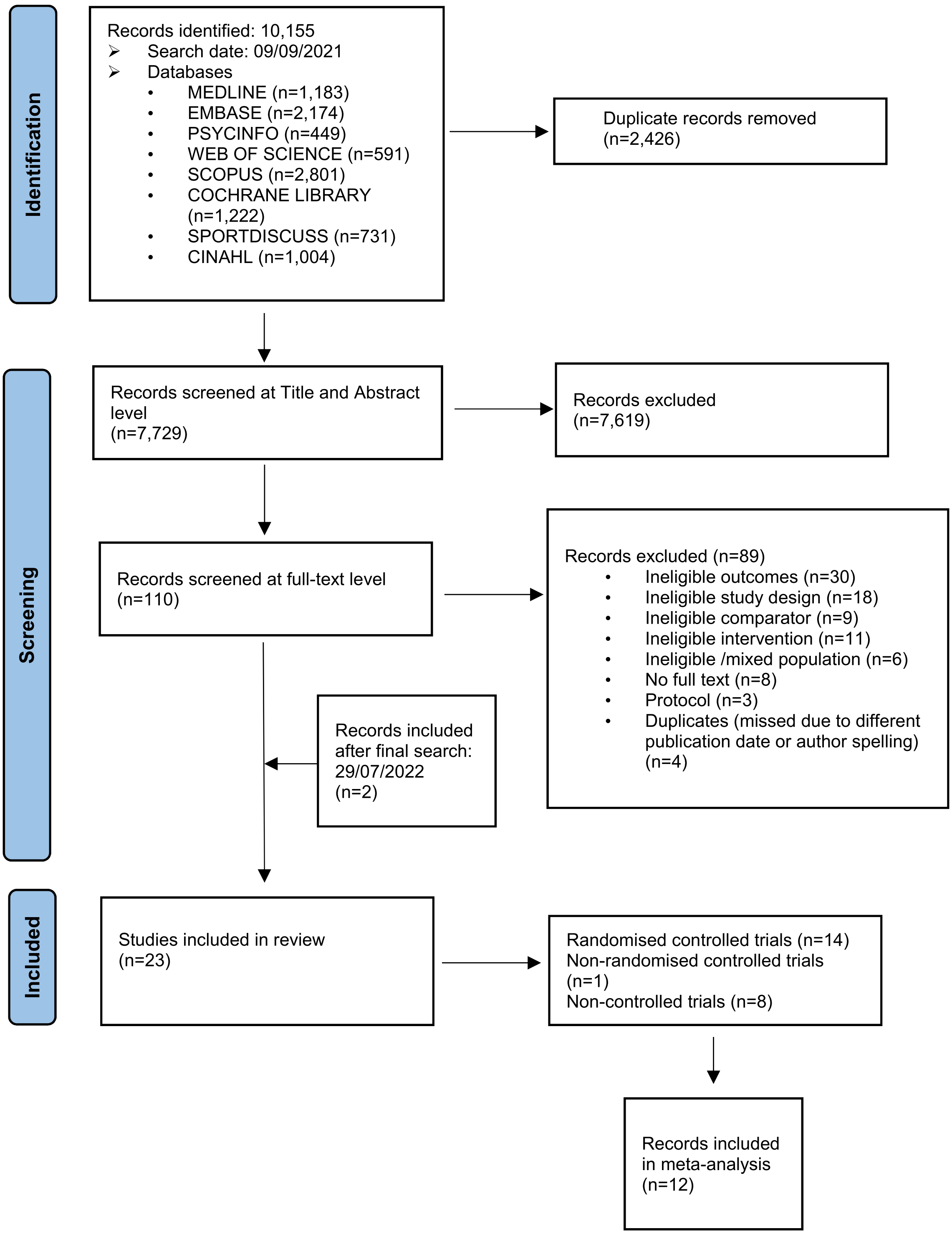

Figure 1. PRISMA flowchart of article screening and selection.

2017; Froehlich-Grobe et al., 2022) being group-based, and five interventions (Basset and Martin Ginis, 2011; Brawley et al., 2013; De Oliveira et al., 2016; Kooijmans et al., 2017; Zemper et al., 2003) having both group and individual components. The interventions were delivered by physical activity specialists (including physiotherapists, exercise physiologists, kinesiologists and experienced exercise counsellors) (n = 8) and intervention researchers (n = 13). Tables 1 and 2 provide a summary of the characteristics of included studies, and Supplements D and E give a detailed description of the interventions and outcomes of the included studies.

Twelve different behaviour change theories or frameworks were referenced across the studies. The Health Action Process Approach (n = 6), Social Cognitive Theory (n = 6), Transtheoretical Model (n = 4), Relapse Prevention Model (n = 2), and Theory of Planned Behaviour (n = 2) were mentioned in more than one study. The Self-Determination Theory, Health Belief Model, Social Learning Model, Self-efficacy Theory and Protection Motivation Theory were mentioned once each. One intervention (Zemper et al., 2003) was framed on the Stuifbergen model. Most theories were applied to interventions (n = 13), whilst four interventions (Bombardier et al., 2021; Hiremath et al., 2019; Nooijen

Table 1
Characteristics of studies included in meta-analysis.

Name/Year	Sample/ Sample after dropout	Duration/ Individualisation/ Provider/Mode/ Setting	Intensity	Theory and application	BCTs	Intervention	Results (measure)	ES
Arbour-Nicitopoulos et al. (2017)	90 77	1 month Individual Researcher Computer Home-based	8	Applied: HAPA	1.4, 4.1, 5.1, 5.6	A toolkit provided information on how to form action plans and identify common barriers to LTPA.	LTPAQ-SCI: Exp: Participants were 1.82 (95% CI 0.58, 5.71) times more likely to participate in one bout of 20 minutes of MVPA than control group.	n/a
Bombardier et al. (2021)	15 14	6 months Individual Exercise professional and psychologist Telephone Home-based	15	Informed: SCT	1.1, 1.2, 1.3, 1.4, 1.5, 1.7, 2.2, 2.3, 9.1, 9.3, 11.2, 12.3	A multi-component intervention consisting of a free home exercise toolkit and a PA counselling curriculum.	PARA-SCI (MVPA): Exp: 39.6 (±47.6) to 70.7 min/wk Con: 29.4 (±52.8) to 17.9 min/wk	0.28
Chemtob et al. (2019), Rocchi et al. (2021)	24 22	8 weeks Individual Kinesiologist Online Home-based	12	Applied: SDT	1.1, 1.2, 1.4, 1.5, 1.6, 2.2, 2.3, 3.1, 3.2, 6.2, 9.2, 13.4, 15.1, 15.3	A weekly exercise and counselling sessions which aimed to foster PA motivation and participation.	LTPAQ-SCI (PA): Exp: 116.7 (±175.54) to 505.82 (±322.84) min/wk Con: 114.17 (±208.82) to 253.36 (±272.15) min/wk	0.85
Froelich-Grobe et al. (2022)	168 120	16 weeks Individual & group Researcher Telephone Home-based	14	Applied: SCT and RPM	1.1, 1.2, 1.4, 2.2, 2.3, 2.4, 3.1, 4.1, 5.1, 9.1	Weekly 60-minute, group-based virtual meetings over Zoom, and access to online self-management and exercise modules.	PAQ (MVPA): Exp: 127.5 (±231.93) to 109.5 (±158.53) min/wk Con: 233.5 (±269.29) to 137.5 (±207.76) min/wk	0.40
Hisham et al. (2022)	44 39	8 weeks Individual Researcher and psychologist In-person and telephone Gym- and home-based	15	No mention	1.1, 1.2, 1.3, 1.4	Circuit aerobic and resistance training with health education training.	PASIPD (PA): Exp: 23.45 (±15.18) to 28.49 (±18.76) min/wk Con: 22.28 (±14.42) to 26.43 (±16.13) min/wk	0.12
Kooijmans et al. (2017)	64 51	16 weeks Individual and group Physical therapist In-person and telephone Clinic- and home-based	14	Applied: TPB and TTM	1.1, 1.3, 1.4, 2.4, 3.1	A home visit followed by group and individual sessions focusing on an active lifestyle and self-management skills.	PASIPD (PA): Exp: 14.3 (±11.6) to 16.7 (±12.1) min/wk Con: 13.2 (±11.4) to 11.3 (±8.5) min/wk	0.17
Latimer et al. (2006)	37 37	8 weeks Individual Researcher Telephone Home-based	10	Applied: TPB	1.1, 1.4, 1.5, 2.3, 3.2, 4.1, 12.5	Three 30-min bouts of MVPA per week with implementation intentions.	PARA-SCI (PA): Exp: 26.79 (±26.65) to 32.77 (±27.18) min/day Con: 15.72 (±17.16) to 14.81 (±19.47) min/day	0.76
Ma et al. (2019)	32 28	9 weeks Individual Researcher In-person or telephone Clinic or home-based	12	Tested: HAPA	1.1, 1.2, 1.4, 1.5, 1.6, 1.8, 1.9, 2.2, 2.3, 3.1, 3.2, 3.3, 4.1, 5.1, 5.3, 5.6, 6.1, 7.1, 8.1, 8.7, 10.2, 10.4, 10.9, 12.1, 12.4, 12.5, 13.1, 13.2	Eight weekly 10- to 15-min behavioural PA coaching sessions tailored to the individual.	LTPAQ-SCI (PA): Exp: 212 (±195) to 405 (±364) min/wk Con: 274 (±300) to 147 (±192) min/wk	0.89
Nightingale et al. (2018)	24 21	6 weeks Individual Researcher In-person and remotely using technology Clinic- and home-based	10	Applied: SCT	2.1, 2.4, 2.6	Exercise sessions four days per week with a heart rate monitor and and monitored progression plan.	PA diary (MVPA): Exp: 13 (±13) to 30 (±19) min/wk Con: 22 (±30) to 19 (±27) min/wk	0.49
Nooijen et al. (2016)	39 38	8 months Individual Physiotherapist and	12	Informed: TTM	1.1, 1.2, 1.4, 2.2, 2.3, 3.1, 3.2, 5.1, 8.1,	A handcycle program three days per week and 13 one-hour face-to-face sessions	PASIPD (PA): Exp: 65 (±27) to 68 (±30) min/day	0.92

(continued on next page)

Table 1 (*continued*)

Name/Year	Sample/ Sample after dropout	Duration/ Individualisation/ Provider/Mode/ Setting	Intensity	Theory and application	BCTs	Intervention	Results (measure)	ES
		occupational therapist In-person and telephone Clinic- and home-based			8.7, 9.1, 12.1, 12.5	focused on PA action plans and barriers.	Con: 80 (±35) to 40 (±31) min/day	
Thomas et al. (2011), Wise et al. (2009)	21 21	3 months Individual Physiotherapist In-person and telephone Home-based	13	Informed: TTM, HBM, SLM, RPM, SET	1.1, 1.2, 2.1, 2.2, 2.3, 3.2, 3.3, 4.1, 5.3, 9.1, 12.5	Individualised instruction on an in-home physical activity program, monitored for three months via telephone calls directed toward goal setting, problem solving, and providing encouragement.	Personal activity log (PA): Exp: 46.5 (±59.9) to 185 (±148.5) min/wk Con: 27 (±35.3) to 94.3 (±76) min/wk	0.78
Zemper et al. (2003)	67 43	7 months Individual and group Researcher In-person and telephone Home-based	13	Applied: Stuifbergen model	1.1, 1.2, 1.4, 1.5	Six 4-hour group workshops over three months. focusing on lifestyle management, PA, nutrition and preventing secondary conditions and individual coaching sessions.	PADQ (PA): Exp: 125.57 (±196.61) to 162.17 (±254.84) min/wk Con: 114.75 (±186.79) to 67.5 (±119.17) min/wk	0.47

Note: BCT = behaviour change theory; ES = effect size; HAPA = health action process approach; MVPA = moderate to vigorous physical activity; PARA-SCI = Physical Activity Recall Assessment for People with Spinal Cord Injury; PA = physical activity; Exp = experimental; Con = control; LTPA = leisure-time physical activity; LTPAQ-SCI = Leisure-time Physical Activity Questionnaire for People with Spinal Cord Injury; CI = confidence interval; SCT – Social Cognitive Theory;; SDT = Self-determination Theory; RPM = Relapse Prevention Model; PAQ = Physical Activity Questionnaire; PASIPD = Physical Activity Scale for Individuals with Physical Disabilities; TPB = Theory of Planned Behaviour; TTM = Transtheoretical Model; HBM = Health Belief Model; SLM = Social Learning Model; SET = Self-efficacy Theory; PADQ = Physical Activities with Disabilities Questionnaire
BCTs are taken from Michie et al., 2013 (definition of each BCT available in Supplement F).
All figures in Results (measure) column are mean ± standard deviation unless otherwise stated.

et al., 2016; Thomas et al., 2011) were informed by theory, one (Ma et al., 2019) tested a theory, and two (de Oliveira et al., 2016; Hisham et al., 2022) made no mention of the use of a theory in developing the intervention.

Inter-coder agreement for BCT coding was 85% (κ = 0.91, PABAK = 0.96) and was classified as 'almost perfect according to McHugh (2012). Forty-six different BCTs were used 194 times across all studies. The average per intervention was 9 (SD6), ranging from 2 to 28. 'Action planning' (n = 16), 'Goal setting (behaviour)' (n = 15), 'Problem--solving' (n = 12), and 'Instruction on how to perform the behaviour' (n = 13) were the most frequent BCTs used. Supplement F gives a description, and the quantity, of each BCT used in the included studies.

5.5. Overall effects and intervention characteristic effects on physical activity

Only controlled studies (Arbour-Nicitopoulos et al., 2017; Bombardier et al., 2021; Chemtob et al., 2019; Froehlich-Grobe et al., 2022; Hisham et al., 2022; Kooijmans et al., 2017; Latimer et al., 2006; Ma et al., 2019; Nightingale et al., 2018; Nooijen et al., 2016; ; Zemper et al., 2003) were included in the meta-analysis. One study (Arbour-Nicitopoulos et al., 2017) provided odds ratio statistics to show how PA behaviour changed. Despite attempts to contact the author, useable PA data for the meta-analysis was not obtained; thus, this study was not included in the meta-analysis.

The overall effect estimate of the change in PA in the controlled trials post-intervention was medium (d = 0.50, 95% CI = 0.31–0.70) in favour of behaviour-targeted interventions. There was no statistical heterogeneity (I^2 = 0%). The MD was an increase of 22.43 min/wk (95% CI = 5.96–38.90, I^2 = 54%) of PA at the end of the intervention. Figure 2 shows the effect size for each study in the form of a forest plot, and Supplement G displays the meta-analysis data.

Three studies (Kooijmans et al., 2017; Nooijen et al., 2016; Thomas et al., 2011) reported follow-up assessment points ranging from 3 to 6 months after the post-intervention assessment. The effect size of change to PA levels at the follow-up assessment was small to medium; however, the 95% CI spanned the line of no difference (d = 0.47, 95% CI = −0.02-0.96). This equated to an MD increase of 25.98 min/week of PA (95% CI = 2.58–49.39). In addition, the sensitivity analysis showed that there was very little difference in effect sizes between the follow-up assessments (d = 0.47, 95% CI = −0.02-0.96) and the post-intervention assessment of all studies (d = 0.50, 95% CI = 0.31–0.70); and between the post-intervention assessment of all studies (d = 0.50, 95% CI = 0.31–0.70) and follow-up assessment of the three studies that reported a follow-up assessment (d = 0.58, 95% CI = 0.11–1.06).

5.6. Duration

Studies with less than 3 months duration (n = 5) had a medium-sized effect (d = 0.60, 95% CI = 0.31-0.90; MD = 13.42min/wk, 95% CI = −5.95-32.80), studies between 3 and 6 months duration (n = 3) had a small to medium-sized effect (d = 0.42, 95% CI = 0.10–0.70; MD = 54.57min/wk, 95% CI = −6.25-115.4) and studies more than 6 months (n = 3) in length had a medium-large sized effect (d = 0.72, 95% CI = 0.2–1.23; MD = 31.28min/wk, 95% CI = 8.97–53.60). The regression analysis between effect size and intervention duration was insignificant (R^2 = 0.14, F(1,9) = 0.13, p = 0.73). The duration of intervention did not predict effect size (β = −0.118, p = 0.73, t(10) = -0.39).

5.7. Provider

Five of the 11 studies were delivered by a physical activity specialist, and six by a researcher. Interventions delivered by a physical activity specialist had a medium-sized effect (d = 0.58, 95% CI = 0.23–0.93; MD = 32.2min/wk, 95% CI = 2.15–62.24), and interventions delivered by a researcher had a medium-sized effect (d = 0.47, 95% CI = 0.23–0.70; MD = 18.37min/wk, 95% CI = −1.39-38.12).

Table 2
Characteristics of studies not included in meta-analysis.

Name/Year	Sample/ Sample after dropout	Duration/ Individualisation/ Provider/Mode/ Setting	Intensity	Theory and application	BCTs	Intervention	Results
Arbour-Nicitopoulos et al. (2009)	44 38	10 weeks Individual Researcher Telephone Home-based	11	Applied: HAPA	1.1, 1.2, 1.4, 1.5, 2.3, 4.1, 7.1, 12.5	Participants formed action plans for 30min of MVPA on three days per week, and barrier management.	PARA-SCI (PA): Exp: 53.8 (+95.9) to 97.8 (+61.1) min/wk Con: 57.1 (±115.1) to 54.5 (±61.1) min/wk over 10 weeks
Arbour-Nicitopoulos et al. (2014)	53 32	6 months Individual Exercise counsellor Telephone Home-based	13	Applied: HAPA	1.2, 1.3, 1.4, 1.9, 3.1, 4.1, 5.3, 6.2, 9.1, 10.3, 12.1, 12.5, 15.1, 15.2	Weekly to monthly counselling calls over six months focusing on behaviour change.	LTPAQ-SCI (number of people who are engaging in ≥30 minutes of MVPA on ≥3 d/wk): Baseline: 16 (35%) Month 6: 24 (15%)
Bassett & Martin Ginis (2011)	62 62	4 weeks Group and individual Researcher Telephone Home-based	11	Applied: PMT	5.1, 5.2	Participants had anthropometric measures taken and results were discussed along with relation to an active lifestyle.	PARA-SCI (PA): Baseline: 18min/d Week 4: 25min/d
Brawley et al. (2013)	13 10	9 weeks Group and individual SCI specialist In-person and telephone Clinic- and home-based	12	Applied: HAPA and SCT	1.1, 1.2, 1.4, 2.2, 2.3, 3.2, 9.1	Structured LTPA program and weekly LTPA behaviour group discussions.	LTPAQ-SCI (PA): Baseline: 42 (±69.57) min/wk Week 9: 197.5 (±270.86) min/wk
de Oliveira et al. (2016)	85 40	3 months Group and individual Exercise professionals In-person Clinic-based	14	No mention	1.1, 2.2, 3.2, 4.1, 6.1, 8.1, 9.1	Weekly PA sessions and feedback on progress with encouragement.	PARA-SCI (PA (median and IQR)): Baseline: 19.8 (0–60) min/wk Month 3: 60 (32.5–70) min/wk
Hiremath et al. (2019)	20 17	3 months Individual Researcher In-person Home-based	12	Informed: SCT	1.3, 2.1, 2.2, 2.4, 4.1, 10.4	Program of 20 min of moderate-to-vigorous intensity aerobic activity, twice per week monitored by a wheel rotation monitor, smartwatch and JITAI.	LTPAQ-SCI (MPA): Baseline phase: 17.7 (±13.8) min/wk PA feedback phase: x23.3 (±19.8) min/wk PA feedback with JITAI phase: 17.5 (±21.6) min/wk
Latimer-Cheung et al. (2013)	12 10	6 weeks Individual Researcher In-person Home-based	11	Applied: SCT	1.1, 1.4, 1.9, 3.2, 4.1, 5.3, 6.1, 8.1, 8.7, 9.1, 12.1, 12.5, 15.1, 15.3	Atrainer and peer established a home exercise strength program for the participant.	LTPAQ-SCI (StPA): Baseline: 30.45 (±37.98) min/wk Week 6: 82.5 (±66.7) min/wk
Tomasone et al. (2016)	46 25	6 months Individual Researcher In-person Home-based	11	Applied: HAPA	1.2, 1.3, 1.4, 1.9, 3., 4.1, 5.3, 6.2, 9.1, 10.3, 12.1, 12.5, 15.1, 15.2	A trainer and peer established a home exercise strength program for the participant.	LTPAQ-SCI (MVPA): Baseline: 61.24 (±110.79) min/wk Month 6: 93.56 (±100.4) min/wk
Warms et al. (2004)	17 16	6 weeks Individual Researcher In-person and telephone Home-based	12	Applied: TTM	1.1, 1.2, 1.4, 1.5, 3.1, 4.1	Home visit for program delivery that was 90 minutes long and included motivational interviewing, goal setting and development of action plans. Included follow-up calls.	Actigraph (activity count): Baseline: 264 (±63) Week 6: 282 (±76)

Note: BCT = behaviour change theory; HAPA = Health Action Process Approach; LTPAQ-SCI = Leisure-time Physical Activity Questionnaire for People with Spinal Cord Injury; MVPA = moderate to vigorous physical activity; PMT = Protection Motivation Theory; PARA-SCI = Physical Activity Recall Assessment for People with Spinal Cord Injury; PA = physical activity; SCT = Social Cognitive Theory; LTPA = Leisure-time physical activity; JITAI = just-in-time-adaptive intervention; StPA = strength physical activity; TTM = Transtheoretical Model
BCTs are taken from Michie et al., 2013 (definition available in Supplement F).
All figures in Results (measure) column are mean ± standard deviation unless otherwise stated.

5.8. Format

Most interventions (n = 8) were administered individually, and only three combined individual and group components. No interventions were solely group based. Interventions completely individualised had a medium-sized effect (d = 0.62, 95% CI = 0.34–0.90; MD = 18.43min/wk, 95% CI = 1.76–35.11) and interventions that included a group and individual component had a small to medium-sized effect (d = 0.39, 95% CI = 0.12–0.66; MD = 54.17min/wk, 95% CI = −8.31-116.64).

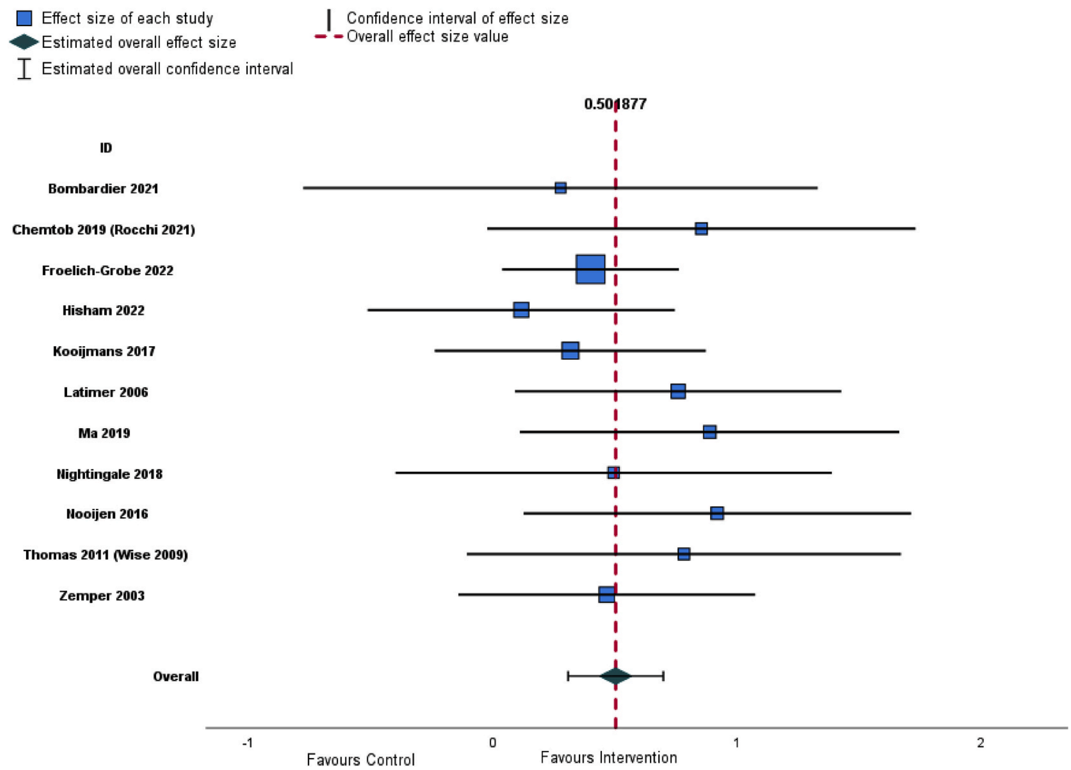

Figure 2. Effect size forest plot

5.9. Mode

The four studies that utilised only technology (telephone, virtual meeting, e-mail) as a means of intervention delivery had a medium-sized combined effect (d = 0.51, 95% CI = 0.29–0.79; MD = 62.22min/wk, 95% CI = −10.49–134.93). The remaining seven interventions contained both an in-person and technology component to intervention delivery, and these had a medium-sized effect (d = 0.50, 95% CI = 0.23–0.76; MD = 19.44min/wk, 95% CI = −0.40-39.28).

5.10. Setting

No interventions were delivered solely at a clinic or gym. Six studies were home-based, and these had a medium-sized effect (d = 0.52, 95% CI = 0.27–0.77; MD = 67.61min/wk, 95% CI = 14.22–121.00). Five studies were home and clinic or gym-based, and these had a slightly lower but still medium-sized effect (d = 0.47, 95% CI = 0.16–0.79; MD = 13.94min/wk, 95% CI = −4.17-32.04).

5.11. Intervention intensity

The regression for intensity was statistically significant ($R^2 = 0.43$, F (1,9) = 6.80, p = 0.028). Intervention intensity did predict effect size ($\beta = -0.66$, p = 0.028, t(10) = -2.61).

5.12. Behaviour change theory

Only one study (Hisham et al., 2022) included in the meta-analysis did not mention a behaviour theory that was used to some capacity in developing and applying the intervention. It had a small-sized effect (that spanned the line of no difference) (d = 0.12, 95% CI = −0.51-0.74; MD = 2.1min/wk, 95% CI = −9.26-13.46) compared to the remaining 10 studies, all of which mentioned the use of a behaviour change theory, and which had a medium-sized effect (d = 0.54, 95% CI = 0.34–0.75; MD = 29.19min/wk, 95% CI = 9.96–48.41). Of the studies which did use a theory, the six that applied a theory had a medium-sized effect (d = 0.48, 95% CI = 0.24–0.71; MD = 23.39min/wk, 95% CI = 1.69–45.09), and the three that were informed by a theory had a medium to large-sized effect (d = 0.72, 95% CI = 0.20–1.23; MD = 31.28min/wk, 95% CI = 8.97–53.60). The remaining study (Ma et al., 2019) tested the Health Action Process Approach and reported one of the largest effect sizes of all interventions (d = 0.89, 95% CI = 0.11–1.66; MD = 258min/wk, 95% CI = 42.43–473.57).

5.13. Behaviour change techniques

There was a statistically significant relationship between the number of BCTs used and the effect size of studies ($R^2 = 0.30$, F(1,9) = 5.25, p = 0.046). BCT quantity did predict effect size ($\beta = 0.61$, p = 0.046, t(10) = -2.31). However, there were no significant differences between the effect sizes of studies that did and did not utilise specific BCTs. Thirteen different BCTs were reported three or more times in the controlled studies, and the effect size differences of studies that did versus did not utilise each BCT ranged from d = 0.00 to d = 0.47. 'Social support (practical)' ($d_{\text{studies that utilised BCT}} = 0.81$, n = 5, 95% CI = 0.46–1.16; $d_{\text{studies that did not utilise BCT}} = 0.34$, n = 6, 95% CI = 0.09–0.58) had the largest difference in favour of the use of the BCT. Other notable differences in effect sizes involved the BCTs 'Adding objects to the environment' ($d_{\text{studies that utilised BCT}} = 0.81$, n = 4, 95% CI = 0.42–1.19; $d_{\text{studies that did not utilise BCT}} = 0.37$, n = 7, 95% CI = 0.14–0.61) and 'Self-monitoring of behaviour' ($d_{\text{studies that utilised BCT}} = 0.59$, n = 7, 95% CI = 0.34–0.83; $d_{\text{studies that did not utilise BCT}} = 0.29$, n = 4, 95% CI = −0.06-0.64). Results for the effect of BCTs are available in Supplement F.

5.14. Quality assessment

Most studies were classified as having a low risk of bias for the first domain (i) randomisation process (n = 10), and only one study (Bombardier et al., 2021) had a bias concern in (ii) deviation from the intended protocol, which was due to a change in exclusion criteria after experiencing difficulties in recruitment. Three studies had a high risk of bias for the (iii) missing outcome data domain; two studies (Froehlich-Grobe et al., 2022; Nooijen et al., 2016) had a substantial amount of missing data due to participant dropout and issues with data collection devices. Three studies (Nooijen et al., 2016; Thomas et al., 2011; Zemper et al., 2003) had underpowered sample sizes. Ten studies were judged to have some concern in (iv) measurement of the outcome due to the assessment tool utilised to capture PA data. Most of the studies utilised self-report measures to assess PA levels. Despite these tools' good criterion validity and test-retest reliability, social desirability is an established common bias for self-reported outcome measures in the general population (Adams et al., 2010). Previous research in the SCI population has shown that there is poor agreement between self-report measures and accelerometers in PA levels of study participants (Ma, McCracken, et al., 2020). Compounding, self-reported PA in people with SCI has been shown to be much lower than reported when using various biometric approaches (Tanhoffer et al., 2012). Thus, these ten studies had some concerns about bias in this domain. The remaining two (Bombardier et al., 2021; Latimer et al., 2006) utilised recall assessments in a semi-structured interview format. From the available information, most studies ($n = 9$) had a low risk of bias for domain five, the selection of reported outcomes. Overall, only four studies (Froehlich-Grobe et al., 2022; Nooijen et al., 2016; Thomas et al., 2011; Zemper et al., 2003) were identified as having a high risk of bias due primarily to missing data and underpowered sample sizes, and the use of PA assessment tools known to result in over-estimation of PA. Results of the bias assessment are available in Supplement I.

An insignificant Egger's test result ($t = 0.1.17$, 95% CI = −1.02-3.30, $p = 0.27$) and visual inspection of the funnel plot (Supplement J) revealed no evidence of publication bias.

6. Discussion

This systematic review and meta-analysis sought to investigate whether interventions that used behaviour change strategies improved PA behaviour in people with SCI. The analysis showed that targeting PA behaviour significantly increased the amount of weekly PA. The medium-sized effect ($d = 0.50$) revealed an average increase in PA by approximately 22min/wk. Whilst no specific intervention characteristic significantly impacted the effect size, some compelling trends supported what is known in this area for people with physical disabilities, and augmented what is established for people with SCI. Reinforcing these findings, the nine non-controlled studies in this review reported an increase in PA by 1.2–3.7 times that of what participants reported at baseline. Together these data can guide future interventions to enhance PA in people with SCI.

Current SCI-specific PA guidelines recommend a minimum of 20 minutes of moderate-to-vigorous intensity aerobic exercise and three sets of muscle-strengthening exercises for each major functional muscle group twice weekly (Martin Ginis et al., 2018). However, a sedentary lifestyle is a recurring global observation in this population as previous research in Thailand (Eitivipart et al., 2021), Canada (Rocchi et al., 2017), Australia (Watson et al., 2022) and Germany (Rauch et al., 2015) has shown that between 48.5% and 50% of adults perform no PA, and for those that do, the recommended levels are generally not met (Hoevenaars et al., 2022; Rauch et al., 2015; Martin Ginis et al., 2021). In addition, it is known that individuals with disabilities are between 16% and 62% less likely to meet PA guidelines than people without disabilities (Martin Ginis et al., 2021), and that the PA levels for people with SCI are twice as low as the global adult population (Bull et al., 2020).

Findings from this review highlighted that by incorporating a behaviour-targeted component to PA interventions, researchers could expect an additional 22min/wk (95% CI = 5.96–38.90) of activity engagement post-intervention. If performed at a moderate intensity, this volume of PA would equate to 55% of the time recommended by the SCI-specific weekly PA guidelines (Martin Ginis et al., 2018) and 15% of the World Health Organization weekly PA recommendations (WHO, 2015). Whilst meeting PA guidelines appears to elicit the most significant healthful change for people with SCI (Martin Ginis et al., 2018), large-scale analysis has shown that even insufficiently active people have reduced all-cause mortality than those who are entirely inactive (O'Donovan et al., 2017). Furthermore, light-intensity PA may induce favourable metabolic changes, particularly for highly sedentary individuals (Powell et al., 2011). Considering that "something is better than nothing", future PA interventions should incorporate BCTs or strategies to some degree, even if this doesn't elicit a guideline-dosage of PA.

The effect of intervention characteristics in our review was consistent with previous research in the SCI-specific and physical disability fields (Ma and Martin Ginis, 2018; Tomasone et al., 2018), with some notable differences. The provider of the intervention, its mode of delivery to the participants, and its setting produced negligible differences in effect sizes between sub-categories. One might conclude this to be a favourable finding considering the COVID-19 pandemic-driven rise in virtual engagement and physical therapy, which allows quick access to care, a reduction in resources and cost, and better continuity of service (Grundstein et al., 2021). An important consideration, however, is that in all analysed studies, the providers were either physical activity specialists or the intervention researcher. In most studies where the researcher delivered the intervention, they had previous experience providing PA services or programming PA for people with SCI or physical disabilities. A lack of knowledge in working with people with physical disabilities has been a cited barrier to PA uptake (Martin Ginis et al., 2016). Considering that most researchers had some experience working with this population, the finding that the intervention provider is irrelevant may be misguided.

Whilst the regression analysis between the duration of the intervention and its effect produced an insignificant finding, interventions that were six or more months in duration had the largest effect size ($d = 0.72$) of all intervention characteristics and was the only modulator that approached a classification of 'large'. However, a wide confidence interval (95% CI from 0.20 to 1.23) suggests a degree of uncertainty with this finding. Furthermore, the small number of interventions that were six months or more in length ($n = 3$) and the insignificant outcome of the duration and effect size regression ($p = 0.73$) don't support the conclusion that the longer the intervention, the more effective it is.

The most notable difference in an intervention characteristic came from its format, with individualised interventions ($d = 0.62$) being markedly more effective than group-based interventions ($d = 0.39$). This outcome is not surprising as research suggests that the exercise responses and capacity for exercise are directly related to the level and completeness of spinal cord injury. Thus both exercise testing and training should be based on individual injury characteristics (Jacobs & Nash, 2004), and researchers need to individualise interventions as much as possible when attempting to improve PA levels in this population.

The intensity of the intervention, unlike previous findings, had a significant relationship with the effect size outcomes, but unexpectantly, it showed that as the intensity increased, the effect size decreased ($\beta = -0.66$, $p = 0.028$). One might expect outcomes to increase as participant contact time and resource allocation increase. Ma and Martin Ginis (2018) reported that their insignificant intensity regression finding had important implications for resource allocation, encouraging more effort to develop theory and (selective) BCT-rich content rather than a complex and highly intensive intervention. Our finding extends their recommendation by suggesting that not only is it important to redirect resources in this manner but there exists a threshold where intensity could be detrimental to the outcome rather than simply insignificant.

Ma et al. (2019) and Nooijen et al. (2016) provide good examples of the relationship between intervention effect size and intensity, as these studies had two of the lowest intensity scores but produced the two highest intervention effect sizes, $d = 0.89$ and $d = 0.92$, respectively. Ma et al. (2019) utilised only eight one-to-fifteen-minute behavioural coaching sessions (delivered once per week across nine weeks) but utilised 28 different BCTs to individualise the intervention. Similarly, Nooijen et al. (2016) used 13 BCTs in individualised action plans for participants, which were administered 13 times across eight months. For the remainder of the time, participants were given an individualised handcycle exercise program to undertake without supervision. Ma and Martin Ginis (2018) offered the possible explanation that the greater time requirements naturally associated with the longer interventions resulted in challenges for participants to sustain their adherence. Ma et al. (2019) and Nooijen et al. (2016) certainly support this claim, as both had the lowest contact time with participants but produced the greatest outcome effects. However, confidence in this finding is limited by the low sample size of the studies included and the potential influence of select BCTs, which were not included in the intensity calculation nor controlled for in the regression model.

A further consideration of the intensity and effect size relationship of the included interventions was that information on settings and reach within interventions were not always clear, and it is possible that some scores did not truly reflect the specific characteristics of interventions that would inform intensity. In fact, previous meta-analysis (Burke et al., 2006) has shown that as the amount of contact and social support available from researchers and health professionals in an intervention increase, so too do the beneficial effects of that intervention for the participants. Further caution should be taken with this finding, as the method used to gauge intensity in interventions to improve PA in people with SCI has not been validated. Researchers should be very diligent and accurate when reporting the characteristics of interventions aimed at improving PA behaviour, namely, the duration of the intervention, the regularity of contact with participants, where and in what format sessions took place, who delivered the intervention, and what specific PA and condition-specific training and experience the intervention deliverers have. The Template for Intervention Description and Replication (TIDiER) checklist (Hoffmann et al., 2014) offers a validated way of providing a comprehensive and reproduceable report of interventions investigated.

Only one included study did not refer to a theory used to structure their intervention (Hisham et al., 2022), and it reported the smallest effect of all studies. Most studies applied a theory; an important finding considering concerns raised by the authors of the theory-application classification system (Painter et al., 2008) utilised in this review, who noted that approximately 70% of theory use (in the general population) was simply informed by theory. Using theories to inform intervention limits the ability to describe how theories are integrated into the measurement, analysis, and design of interventions, making replication and comparison of results difficult. It also relies on more significant reader inference to understand the actual impact of the theory on the outcomes. Applying a theory appears to utilise more of the theory constructs than when a theory simply informs the intervention, whilst still allowing for a degree of flexibility with the intervention modulators such as intensity and duration.

The average effect of the studies that were informed by theory in our review were higher (d = 0.72, 95% CI = 0.20–1.23) than studies that applied a theory (d = 0.48, 95% CI = 0.24–0.71). Still, the interpretation of this finding should be tempered by consideration of the informed theory group's large confidence interval compared with the effect size confidence intervals of the applied-theory interventions. The more utilised a behaviour change theory is in developing an intervention, the more effective it appears to be (Brug et al., 2005), and not only does health behaviour theory guide the design of the intervention, it also identifies the aspects or "active ingredients" responsible for the change (Rogers et al., 2018). Michie and Prestwich (2010) have listed numerous arguments in favour of the explicit use of theory, including greater intervention effects when interventions target theory-identified constructs thought to change behaviour. Ma and colleagues' (Ma et al., 2019) study included in this review highlights this, as it was the only study that employed an intervention that tested a theory; and produced the outcome of greatest effect-size. In addition, researchers would benefit from incorporating stakeholders into the design of interventions. Ma et al. (2019) heavily incorporated stakeholders into the design of the intervention (Ma, Cheifetz, et al., 2020), which might have accounted for the largest effect size across the included studies. Consumer engagement in co-design has been shown to facilitate the translation of research into practice (Rosenkranz et al., 2021) and assists in addressing the numerous condition-specific barriers (Dinwoodie et al., 2022) identified in the population. Research amalgamating efficacious behaviour change frameworks and end-user involvement is beginning to emerge (Lawrason et al., 2022) in the SCI and PA field, and researchers looking to address this critical issue should follow suit.

Contrary to previous research, the number of distinct BCTs employed did make a difference in PA outcomes. However, as with our other regression results, caution is encouraged in interpreting this finding due to the small number of studies included in the analysis. This finding, nonetheless, corroborates the emerging theme that resources are better spent on utilising specific BCT content and theory-rich (rather than complex and prolonged) interventions. This is reinforced by findings on self-management and PA in people with SCI (Tomasone et al., 2018).

Whilst the most common BCTs utilised were goal setting, problem-solving and action planning, the greatest differences in effect sizes were associated with self-monitoring and practical social support. A previous meta-analysis of more heterogenous studies has shown that BCTs that utilise self-regulation, specifically goal setting and self-monitoring of behaviour, have been associated with successful intervention outcomes in both the short and long term (Samdal et al., 2017), and self-monitoring using simple and readily available technology is one of the most effective ways to improve participation in PA (Page et al., 2020).

Feedback of behaviour provided by others was also a frequently utilised BCT in the included studies in this review but was significantly less influential on the effect sizes between studies that did and did not utilise it. Whilst providing formative feedback to participants is important, it appears that self-monitoring, similar to other chronic populations (Gleeson-Kreig, 2006; Vooijs et al., 2014), plays a more impactful role in PA behaviour in people with SCI, but an interweave of self-monitoring components (e.g., goal-setting and feedback) is more effective at facilitating behaviour change (Kazdin, 1974) than when used in isolation. Thus, participants should be given this measure of autonomy and responsibility in future interventions in this field.

Practical social support offers participant-specific assistance with the performance of the desired behaviour. It is not surprising that this BCT elicited greater PA outcomes in studies that utilised it, considering the myriad of clinical presentations associated with paralysis due to SCI and that individualisation of PA programs is encouraged (Jacobs & Nash, 2004). Additionally, the number of reported barriers (Dinwoodie et al., 2022) faced by people with SCI to engage in PA would naturally drive a need for support, most likely in the initial phases of an intervention, especially considering that a lack of PA knowledge is a regularly reported issue for people with physical disabilities (Williams et al., 2017). The findings in this review encourage a supportive environment and the provision of regular contact with interventionists to maximise PA outcomes.

6.1. Implications and limitations

Our findings offer researchers and practitioners valuable information for developing or initiating change toward positive and healthful PA behaviour. Whilst the results in this review align with the recommendations for PA adherence in people with chronic disease and the elderly (Collado-Mateo et al., 2021), it appears that some aspects of interventions carry more impact than others on driving change in the SCI population.

Individualisation of programs is essential to maximise intervention outcomes, and intervention developers should involve the participant in the process of intervention development. Individualisation is often necessary due to the vast spectrum of clinical presentation and heterogenic nature of the 'incomplete' SCI population, so ensuring that PA programs are catered toward each participant allows for the maximum potential of the PA outcome. Concurrently, end-users should be given a degree of responsibility in self-monitoring of their PA adherence, and intervention providers should be readily available to assist participants whilst proactively offering support and positive feedback. Considering that a lack of knowledge is a prevailing barrier to PA engagement in people with SCI (and in the chronic disease population) (Collado-Mateo et al., 2021; Kehn & Kroll, 2009), provisions and education should be provided to participants before commencement and throughout interventions to maximise uptake and adherence.

Researchers should ensure detailed and diligent reporting of intervention parameters so that interventions can be replicated and implemented in the community. Taxonomies such as Michie and colleagues' (Michie et al., 2013) and reporting frameworks such as the TIDiER checklist (Hoffmann et al., 2014) offer valuable methods to catalogue components of behaviour-change mechanisms for straightforward interpretation and implementation by others. Considering that the sheer dose of behaviour change content does not elicit the greatest degree of positive change, researchers should ensure (in the same way as intervention characteristics) that behaviour change components are specific to the individual and target autonomy, self-efficacy and barrier management. In addition, the literature (Adams et al., 2010; Ma, McCracken, et al., 2020; Tanhoffer et al., 2012) indicates that a dual approach of self-reporting with the use of accelerometry or biometric measures would produce the most accurate PA level data of participants; and this should be considered in future interventions.

A few limitations of results and considerations of implications warrant mention. First, as has been discussed already, the small number of studies in the meta-analysis limits confidence in findings, and more studies are needed to provide more robust evidence for the effects. This is especially true for the results of the regression analysis of intervention intensity and the relationship between the number of BCTs used and the effect sizes for interventions. In addition to the general findings, the low number of studies made a more comprehensive analysis of intervention characteristics futile. The effect of specific BCTs and characteristics of interventions via meta-regression would produce insightful data and help to identify how study-level characteristics account for heterogeneity. But with so many covariates and so few studies, meta-regression data would have been ambiguous.

Second, only 45 of the 93 hierarchical clustered BCTs have been used in PA behaviour change interventions for people with SCI. Whilst data herein revealed which BCTs appear to be effective in eliciting healthful change to PA behaviour, other un-tested BCTs may offer greater positive effects on PA behaviour.

Third, most studies were conducted in high-income countries, which gives incertitude to whether intervention outcomes would be similar in low-income countries, especially considering that PA promotion strategies are fewer (Giouridis et al., 2021), reported comorbidities are higher (Ona et al., 2021) and barriers to PA are less understood (Tomasone et al., 2022).

Many of the studies included in the meta-analysis contained a participant inclusion pre-requisite of being physically inactive (but there were differences in the definition of 'physical inactivity' between studies). However, according to the available data, the intervention group's combined average amount of PA at baseline was 81.5 (±124.8) min/wk, and the control group's combined averaged amount of PA at baseline was 76.8 (±128.8) min/wk. It therefore appears that participants, on average, were not physically inactive. A possible explanation for this discrepancy is a significant spread of baseline PA values within studies, low sample sizes, and some influencing outlier scores, which is supported by the large standard deviations of both values. In addition, research has repeatedly shown that high proportions of people with SCI are physically inactive (Eitivipart et al., 2021; Martin Ginis et al., 2010; Rauch et al., 2015), which further contradicts the baseline values reported here. The conflicting information makes it difficult to say with certainty that the additional 22 min/wk of PA that behaviour-targeted intervention offers would result in individuals meeting or exceeding guideline-recommeded levels of PA (Martin Ginis et al., 2018) at the population level. But based on reported inactivity levels, it would undoubtedly have a positive impact. More detail on participant PA levels at baseline and the end of each intervention, specifically around the volume of aerobic and resistance PA, would provide insightful data on the critical issue of physical inactivity in people with SCI.

Likewise, within studies, the mean difference in min/wk of PA between baseline and post-intervention assessment points was not always clear. In some studies, the modified use of recall assessments, a transformation of raw data, and pooling of (various types of PA) min/wk values made discerning the actual change in min/wk of PA difficult. In all instances, we chose the most conservative value or option to include in the meta-analysis for min/wk calculations. Therefore, there exists the possibility that the min/wk values reported in this review under-represent the actual additional volume of PA that would be undertaken overall, and with the influence of each moderator. Considering this, and the large confidence intervals associated with all the min/wk values in this review (some of which cross the line of no effect), the SMD value provides the most accurate numerical representation of the impact of behaviour-change on PA. We would encourage clear and distinct reporting of PA values within future research so useful data can be easily drawn.

Finally, two BCTs, 'Goal setting (outcome)' and 'Action planning', appeared to reduce the effect size of interventions when they were used as opposed to when they were not used (Supplement F). However, both BCTs were significantly imbalanced in the times used compared to unused in the effect size difference calculation. Coupled with the overall low number of studies included in this portion of the meta-analysis, concluding that these BCTs negatively impact PA change in people with SCI would be premature.

7. Conclusion

Interventions that utilise behaviour-change techniques and strategies are moderately effective in improving PA levels in people with SCI. Individualised interventions that maximise the application of established behaviour change frameworks and utilise specific BCTs, especially those associated with monitoring and access to practical support, appear to be more effective than interventions that use theories that are applied broadly. Considering extensive barriers, increased incidence of comorbidities, insufficient energy expenditure, and the generally low levels of PA within this population, practitioners and researchers should treat behaviour modification as a critical component of interventions to improve PA for people with SCI. Future research should examine the discrete effectiveness of the most utilised behaviour change techniques in studies that report improvements in PA uptake and levels, and ensure detailed reporting of intervention characteristics and behaviour-targeting methodologies.

Funding and conflicts of interest

Spinal Cord Injuries Australia supported this work through a PhD scholarship for the first author (PW). However, the funders were not involved in the study design, collection, analysis and interpretation of data, the writing of the manuscript, or the decision to submit the manuscript for publication.

We have no known conflict of interest to disclose.

Data availability

The authors do not have permission to share data.

Acknowledgements

The authors would like to acknowledge the assistance of Dr Yulia Ulyannikova, Academic Liaison Librarian at the Sydney Pharmacy School, School of Medical Sciences, Northern Clinical School, the University of Sydney, for her assistance in the literature search.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2023.102408.

References

Adams, S. A., Matthews, C. E., Ebbeling, C. B., Moore, C. G., Cunningham, J. E., Fulton, J., & Hebert, J. R. (2010). The effect of social desirability and social approval on self-reports of physical activity. *American Journal of Epidemiology, 161*(4), 389–398. https://doi.org/10.1093/aje/kwi054

Anderson, E., & Durstine, J. L. (2019). Physical activity, exercise, and chronic diseases: A brief review. *Sports Medicine and Health Science, 1*(1), 3–10. https://doi.org/10.1016/j.smhs.2019.08.006

Arbour-Nicitopoulos, K. P., Ginis, K. A. M., & Latimer, A. (2009). Planning, leisure-time physical activity, and coping self-efficacy in persons with spinal cord injury: A randomised controlled trial. *Archives of Physical Medicine and Rehabilitation, 90*(12), 2003–2011. https://doi.org/10.1016/j.apmr.2009.06.019

Arbour-Nicitopoulos, K. P., Sweet, S. N., Lamontagne, M. E., Ginis, K. A. M., Jeske, S., Routhier, F., & Latimer-Cheung, A. E. (2017). A randomised controlled trial to test the efficacy of the SCI Get Fit Toolkit on leisure-time physical activity behaviour and social-cognitive processes in adults with spinal cord injury. *Spinal Cord Series and Cases, 3*(1). https://doi.org/10.1038/scsandc.2017.44

Arbour-Nicitopoulos, K. P., Tomasone, J. R., Latimer-Cheung, A. E., & Martin Ginis, K. A. (2014). Get in motion: An evaluation of the reach and effectiveness of a physical activity telephone counseling service for Canadians living with spinal cord injury. *Philosophy and Medicine R, 6*(12), 1088–1096. https://doi.org/10.1016/j.pmrj.2014.05.018

Babineau, J. (2014). Product review: Covidence (systematic review software). *Journal of the Canadian Health Libraries Association, 35*(2), 68–71. https://doi.org/10.5596/c14-016

Bassett, R. L., & Martin Ginis, K. A. (2011). Risky business: The effects of an individualised health information intervention on health risk perceptions and leisure time physical activity among people with spinal cord injury. *Disability and Health Journal, 4*(3), 165–176. https://doi.org/10.1016/j.dhjo.2010.12.001

Bombardier, C. H., Dyer, J. R., Burns, P., Crane, D. A., Takahashi, M. M., Barber, J., & Nash, M. S. (2021). A tele-health intervention to increase physical fitness in people with spinal cord injury and cardiometabolic disease or risk factors: A pilot randomized controlled trial. *Spinal Cord, 59*(1), 63–73. https://doi.org/10.1038/s41393-020-0523-6

Borstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis*. Wiley and Sons.

Brand, R., & Cheval, B. (2019). Theories to explain exercise motivation and physical inactivity: Ways of expanding our current theoretical perspective. *Frontiers in Psychology, 10*. https://doi.org/10.3389/fpsyg.2019.01147

Brawley, L. R., Arbour-Nicitopoulos, K. P., & Martin Ginis, K. A. (2013). Developing physical activity interventions for adults with spinal cord injury. Part 3: A pilot feasibility study of an intervention to increase self-managed physical activity. *Rehabilitation Psychology, 58*(3), 316–321. https://doi.org/10.1037/a0032814

Brug, J., Oenema, A., & Ferreira, I. (2005). Theory, Evidence and Intervention Mapping to improve behavior nutrition and physical activity interventions. *International Journal of Behavioral Nutrition and Physical Activity, 2*(1), 2. https://doi.org/10.1186/1479-5868-2-2

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J. P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., … Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine, 54*(24), 1451–1462. https://doi.org/10.1136/bjsports-2020-102955

Burke, S. M., Carron, A. V., Eys, M. A., Ntoumanis, N., & Estabrooks, P. A. (2006). Group versus individual approach? A meta-analysis of the effectiveness of interventions to promote physical activity. *Journal of Sport & Exercise Psychology, 2*, 19–35.

Chemtob, K., Rocchi, M., Arbour-Nicitopoulos, K., Kairy, D., Fillion, B., & Sweet, S. (2019). Using tele-health to enhance motivation, leisure time physical activity, and quality of life in adults with spinal cord injury: A self-determination theory-based pilot randomised control trial. *Psychology of Sport and Exercise, 43*, 243–252. https://doi.org/10.1016/j.psychsport.2019.03.008

Cohen, J. (2013). In *Statistical power analysis for the behavioral Sciences*. https://doi.org/10.4324/9780203771587

Collado-Mateo, D., Lavín-Pérez, A. M., Peñacoba, C., Del Coso, J., Leyton-Román, M., Luque-Casado, A., Gasque, P., Fernández-Del-Olmo, M.Á., & Amado-Alonso, D. (2021). Key factors associated with adherence to physical exercise in patients with chronic diseases and older adults: An umbrella review. *International Journal of Environmental Research and Public Health, 18*(4), 2023. https://doi.org/10.3390/ijerph18042023

Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behaviour and behaviour change across the social and behavioural sciences: A scoping review. *Health Psychology Review, 9*(3), 323–344. https://doi.org/10.1080/17437199.2014.941722

Der Simonian, R., & Laird, N. (1986). Meta-analysis in clinical trials. *Controlled Clinical Trials, 7*(3), 177–188. https://doi.org/10.1016/0197-2456(86)90046-2

Dettori, J. R., Norvell, D. C., & Chapman, J. R. (2022). Fixed-effect vs random-effects models for meta-analysis: 3 points to consider. *Global Spine Journal, 12*(7), 1624–1626. https://doi.org/10.1177/21925682221110527

Dinwoodie, M., Hoekstra, F., Stelzer, S., Ma, J. K., & Martin Ginis, K. A. (2022). A dynamic analysis of physical activity barriers experienced by adults with spinal cord injury. *Spinal cord series and cases, 8*(1), 37. https://doi.org/10.1038/s41394-022-00504-y

Eitivipart, A. C., Arora, M., Quel De Oliveira, C., Heard, R., Middleton, J. W., & Davis, G. M. (2021). Assessing physical activity and health-related quality of life in individuals with spinal cord injury: A national survey in Thailand. *Disability & Rehabilitation*, 1–11. https://doi.org/10.1080/09638288.2021.1979665

Fekete, C., & Rauch, A. (2012). Correlates and determinants of physical activity in persons with spinal cord injury: A review using the international classification of functioning, disability and health as reference framework. *Disability and health journal, 5*(3), 140–150. https://doi.org/10.1016/j.dhjo.2012.04.003

Froehlich-Grobe, K., Lee, J., Ochoa, C., Lopez, A., Sarker, E., Driver, S., Shegog, R., & Lin, S. J. (2022). Effectiveness and feasibility of the workout on wheels internet intervention (WOWii) for individuals with spinal cord injury: A randomised controlled trial. *Spinal Cord, 26*, 1–13. htt ps://doi.10.1038/s41393-022-00787-w.

Giouridis, N., Williams, T. L., & Tomasone, J. R. (2021). Physical activity promotion to persons with spinal cord injury by health and exercise professionals: A scoping review. *The Journal of Spinal Cord Medicine*, 1–20. https://doi.org/10.1080/10790268.2021.1977061

Gleeson-Kreig, J. M. (2006). Self-monitoring of physical activity: Effects on self-efficacy and behavior in people with type 2 diabetes. *The Diabetes Educator, 32*(1), 69–77. https://doi.org/10.1177/0145721705284285

Grundstein, M. J., Fisher, C., Titmuss, M., & Cioppa-Mosca, J. (2021). The role of virtual physical therapy in a post–pandemic world: Pearls, pitfalls, challenges, and adaptations. *Physical Therapy, 101*. https://doi.org/10.1093/ptj/pzab145

Hagger, M. S., & Weed, M. (2019). Debate: Do interventions based on behavioral theory work in the real world? *International Journal of Behavioral Nutrition and Physical Activity, 16*(1). https://doi.org/10.1186/s12966-019-0795-4

Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., Macera, C. A., Heath, G. W., Thompson, P. D., & Bauman, A. (2007). Physical activity and public health: Updated recommendation for adults from the American college of sports medicine and the American heart association. *Medicine & Science in Sports & Exercise, 39*(8), 1423–1434. https://doi.org/10.1249/mss.0b013e3180616b27

Hendrie, G. A., Brindal, E., Baird, D., & Gardner, C. (2013). Improving children's dairy food and calcium intake: Can intervention work? A systematic review of the literature. *Public Health Nutrition, 16*(2), 365–376. https://doi.org/10.1017/S1368980012001322

Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (Eds.). (2022). *Cochrane Handbook for systematic reviews of interventions*. updated February version 6.3. .

Hiremath, S. V., Amiri, A. M., Thapa-Chhetry, B., Snethen, G., Schmidt-Read, M., Ramos-Lamboy, M., Coffman, D. L., & Intille, S. S. (2019). Mobile health-based physical activity intervention for individuals with spinal cord injury in the community: A pilot study. *PLoS One, 14*(10), Article e0223762. https://doi.org/10.1371/journal.pone.0223762

Hisham, H., Justine, M., Hasnan, N., & Manaf, H. (2022). Effects of paraplegia fitness integrated training on physical function and exercise self-efficacy and adherence among individuals with spinal cord injury. *Annals of Rehabilitation Medicine, 46*(1), 33–44. https://doi.org/10.5535/arm.21127

Hoevenaars, D., Holla, J. F. M., Postma, K., van der Woude, L. H. V., Janssen, T. W. J., & de Groot, S. (2022). In *Associations between meeting exercise guidelines, physical fitness, and health in people with spinal cord injury.Disability and rehabilitation* (pp. 1–8). Advance online publication. https://doi.org/10.1080/09638288.2022.2048910.

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., Altman, D. G., Barbour, V., Macdonald, H., Johnston, M., Lamb, S. E., Dixon-Woods, M., McCulloch, P., Wyatt, J. C., Chan, A. W., & Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ, 348*. https://doi.org/10.1136/bmj.g1687 (mar07 3), g1687.

Jacobs, P. L., & Nash, M. S. (2004). Exercise recommendations for individuals with spinal cord injury. *Sports Medicine, 34*, 727–751. https://doi.org/10.2165/00007256-200434110-00003

Johnson, R. L., Gerhart, K. A., McCray, J., Menconi, J. C., & Whiteneck, G. G. (1998). Secondary conditions following spinal cord injury in a population-based sample. *Spinal Cord, 36*(1), 45–50. https://doi.org/10.1038/sj.sc.3100494

Kawanishi, C. Y., & Greguol, M. (2013). Physical activity, quality of life, and functional autonomy of adults with spinal cord injuries. *Adapted Physical Activity Quarterly: Adapted Physical Activity Quarterly, 30*(4), 317–337. https://doi.org/10.1123/apaq.30.4.317

Kazdin, A. E. (1974). Reactive self-monitoring: The effects of response desirability, goal setting, and feedback. *Journal of Consulting and Clinical Psychology, 42*(5), 704–716. https://doi.org/10.1037/h0037050

Kehn, M., & Kroll, T. (2009). Staying physically active after spinal cord injury: a qualitative exploration of barriers and facilitators to exercise participation. *BMC Public Health, 9*(1), 168. https://doi.org/10.1186/1471-2458-9-168

Kooijmans, H., Post, M. W. M., Stam, H. J., van der Woude, L. H. V., Spijkerman, D. C. M., Snoek, G. J., Bongers-Janssen, H. M. H., van Koppenhagen, C. F., Twisk, J. W., & Bussmann, J. B. J. (2017). Effectiveness of a self-management intervention to promote an active lifestyle in persons with long-term spinal cord injury: The HABITS randomised clinical trial. *Neurorehabilitation and Neural Repair, 31*(12), 991–1004. https://doi.org/10.1177/1545968317736819

Krause, J. S. (1998). Aging and life adjustment after spinal cord injury. *Spinal Cord, 36* (5), 320–328. https://doi.org/10.1038/sj.sc.3100540

Latimer-Cheung, A. E., Arbour-Nicitopoulos, K. P., Brawley, L. R., Gray, C., Justine Wilson, A., Prapavessis, H., Tomasone, J. R., Wolfe, D. L., & Martin Ginis, K. A. (2013). Developing physical activity interventions for adults with spinal cord injury. Part 2: Motivational counseling and peer-mediated interventions for people intending to be active. *Rehabilitation Psychology, 58*(3), 307–315.

Latimer, A. E., Ginis, K. A. M., & Arbour, K. P. (2006). The efficacy of an implementation intention intervention for promoting physical activity among individuals with spinal cord injury: A randomised controlled trial. *Rehabilitation Psychology, 51*(4), 273–280. https://doi.org/10.1037/0090-5550.51.4.273

Lawrason, S. V. C., Brown-Ganzert, L., Campeau, L., Macinnes, M., Wilkins, C. J., & Martin Ginis, K. A. (2022). mHealth physical activity intervention for individuals with spinal cord injury: Planning and development processes. *JMIR Formative Research, 6*(8), Article e34303. https://doi.org/10.2196/34303

Ma, J. K., Cheifetz, O., Todd, K. R., Chebaro, C., Phang, S. H., Shaw, R. B., Whaley, K. J., & Martin Ginis, K. A. (2020). Co-development of a physiotherapist-delivered physical activity intervention for adults with spinal cord injury. *Spinal Cord, 58*(7), 778–786. https://doi.org/10.1038/s41393-020-0422-x

Ma, J. K., & Martin Ginis, K. A. (2018). A meta-analysis of physical activity interventions in people with physical disabilities: Content, characteristics, and effects on behaviour. *Psychology of Sport and Exercise, 37*, 262–273. https://doi.org/10.1016/j.psychsport.2018.01.006

Ma, J. K., McCracken, L. A., Voss, C., Chan, F. H. N., West, C. R., & Martin Ginis, K. A. (2020). Physical activity measurement in people with spinal cord injury: Comparison of accelerometry and self-report (the physical activity recall assessment for people with spinal cord injury). *Disability & Rehabilitation, 42*(2), 240–246. https://doi.org/10.1080/09638288.2018.1494213

Martin Ginis, K. A., Latimer, A. E., Arbour-Nicitopoulos, K. P., Buchholz, A. C., Bray, S. R., Craven, B. C., Hayes, K. C., Hicks, A. L., McColl, M. A., Potter, P. J., Smith, K., & Wolfe, D. L. (2010). Leisure time physical activity in a population-based sample of people with spinal cord injury Part I: Demographic and injury-related correlates. *Archives of Physical Medicine and Rehabilitation, 91*(5), 722–728. https://doi.org/10.1016/j.apmr.2009.12.027

Martin Ginis, K. A., Ma, J. K., Latimer-Cheung, A. E., & Rimmer, J. H. (2016). A systematic review of review articles addressing factors related to physical activity participation among children and adults with physical disabilities. *Health Psychology Review, 10*(4), 478–494. https://doi.org/10.1080/17437199.2016.1198240

Martin Ginis, K. A., Van Der Ploeg, H. P., Foster, C., Lai, B., Mcbride, C. B., Ng, K., … Heath, G. W. (2021). Participation of people living with disabilities in physical activity: A global perspective. *The Lancet, 398*, 443–455. https://doi.org/10.1016/s0140-6736(21)01164-8

Martin Ginis, K. A., van der Scheer, J. W., Latimer-Cheung, A. E., Barrow, A., Bourne, C., Carruthers, P., Bernardi, M., Ditor, D. S., Gaudet, S., de Groot, S., Hayes, K. C., Hicks, A. L., Leicht, C. A., Lexell, J., Macaluso, S., Manns, P. J., McBride, C. B., Noonan, V. K., Pomerleau, P., … Goosey-Tolfrey, V. L. (2018). Evidence-based scientific exercise guidelines for adults with spinal cord injury: An update and a new guideline. *Spinal Cord, 56*(4), 308–321. https://doi.org/10.1038/s41393-017-0017-3

Ma, J. K., West, C. R., & Martin Ginis, K. A. (2019). The effects of a patient and provider Co-developed, behavioral physical activity intervention on physical activity, psychosocial predictors, and fitness in individuals with spinal cord injury: A randomised controlled trial. *Sports Medicine, 49*(7), 1117–1131. https://doi.org/10.1007/s40279-019-01118-5

Maynard, F. M., Jr., Bracken, M. B., Creasey, G., Ditunno, J. F., Jr., Donovan, W. H., Ducker, T. B., Garber, S. L., Marino, R. J., Stover, S. L., Tator, C. H., Waters, R. L., Wilberger, J. E., & Young, W. (1997). International standards for neurological and functional classification of spinal cord injury. American spinal injury association. *Spinal Cord, 35*(5), 266–274. htt ps://doi.10.1038/sj.sc.3100432.

McHugh, ML. (2012). Interrater reliability: the kappa statistic. *Biochem Med (Zagreb), 22* (3), 276–282.

Michie, S., & Prestwich, A. (2010). Are interventions theory-based? Development of a theory coding scheme. *Health Psychology: Official Journal of the Division of Health Psychology, American Psychological Association, 29*(1), 1–8. https://doi.org/10.1037/a0016939

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M. P., Cane, J., & Wood, C. E. (2013). 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, 46*(1), 81–95. https://doi.org/10.1007/s12160-013-9486-6

Mikkelsen, K., Stojanovska, L., Polenakovic, M., Bosevski, M., & Apostolopoulos, V. (2017). Exercise and mental health. *Maturitas, 106*, 48–56. https://doi.org/10.1016/j.maturitas.2017.09.003

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews, 4*(1). https://doi.org/10.1186/2046-4053-4-1

Morrison, A., Polisena, J., Husereau, D., Moulton, K., Clark, M., Fiander, M., Mierzwinski-Urban, M., Clifford, T., Hutton, B., & Rabb, D. (2012). The effect of English-language restriction on systematic review-based meta-analyses: A systematic review of empirical studies. *International Journal of Technology Assessment in Health Care, 28*(2), 138–144. https://doi.org/10.1017/s0266462312000086

Nightingale, T. E., Rouse, P. C., Walhin, J. P., Thompson, D., & Bilzon, J. L. (2018). Home-based exercise enhances health-related quality of life in persons with spinal cord injury: A randomised controlled trial. *Archives of Physical Medicine and Rehabilitation, 99*(10). https://doi.org/10.1016/j.apmr.2018.05.008, 1998–2006.e1.

Nooijen, C. F., Stam, H. J., Bergen, M. P., Bongers-Janssen, H. M., Valent, L., van Langeveld, S., Twisk, J., & van den Berg-Emons, R. J. (2016). A behavioural intervention increases physical activity in people with subacute spinal cord injury: A randomised trial. *Journal of Physiotherapy, 62*(1), 35–41. https://doi.org/10.1016/j.jphys.2015.11.003

Nystoriak, M. A., & Bhatnagar, A. (2018). Cardiovascular effects and benefits of exercise. *Frontiers in Cardiovascular Medicine, 5*. https://doi.org/10.3389/fcvm.2018.00135

O'Donovan, G., Lee, I.-M., Hamer, M., & Stamatakis, E. (2017). Association of "weekend warrior" and other leisure time physical activity patterns with risks for all-cause, cardiovascular disease, and cancer mortality. *JAMA Internal Medicine, 177*(3), 335. https://doi.org/10.1001/jamainternmed.2016.8014

Olander, E. K., Fletcher, H., Williams, S., Atkinson, L., Turner, A., & French, D. P. (2013). What are the most effective techniques in changing obese individuals' physical activity self-efficacy and behaviour: A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity, 10*, 29. https://doi.org/10.1186/1479-5868-10-29

de Oliveira, B. I. R., Howie, E. K., Dunlop, S. A., Galea, M. P., McManus, A., & Allison, G. T. (2016). SCIPA com: Outcomes from the spinal cord injury and physical activity in the community intervention. *Spinal Cord, 54*(10), 855–860. https://doi.org/10.1038/sc.2015.235

Oña, A., Strøm, V., Lee, B. S., Le Fort, M., Middleton, J., Gutenbrunner, C., & Pacheco Barzallo, D. (2021). Health inequalities and income for people with spinal cord injury. A comparison between and within countries. *SSM - population health, 15*, Article 100854. https://doi.org/10.1016/j.ssmph.2021.100854

Page, E. J., Massey, A. S., Prado-Romero, P. N., & Albadawi, S. (2020). The use of self-monitoring and technology to increase physical activity: A review of the literature. *Perspectives on Behavior Science, 43*(3), 501–514. https://doi.org/10.1007/s40614-020-00260-0

Painter, J. E., Borba, C. P., Hynes, M., Mays, D., & Glanz, K. (2008). The use of theory in health behavior research from 2000 to 2005: A systematic review. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine, 35*(3), 358–362. https://doi.org/10.1007/s12160-008-9042-y

Powell, K. E., Paluch, A. E., & Blair, S. N. (2011). Physical activity for health: What kind? How much? How intense? On top of what? *Annual Review of Public Health, 32*, 349–365. https://doi.org/10.1146/annurev-publhealth-031210-101151

Rauch, A., Hinrichs, T., Oberhauser, C., & Cieza, A. (2015). Do people with spinal cord injury meet the WHO recommendations on physical activity? *International Journal of Public Health, 61*(1), 17–27. https://doi.org/10.1007/s00038-015-0724-5

Rhodes, R. E., Boudreau, P., Josefsson, K. W., & Ivarsson, A. (2021). Mediators of physical activity behaviour change interventions among adults: A systematic review and meta-analysis. *Health Psychology Review, 15*(2), 272–286. https://doi.org/10.1080/17437199.2019.1706614

Rocchi, M. A., Robichaud Lapointe, T., Gainforth, H. L., Chemtob, K., Arbour-Nicitopoulos, K. P., Kairy, D., & Sweet, S. N. (2021). Delivering a tele-health intervention promoting motivation and leisure-time physical activity among adults with spinal cord injury: An implementation evaluation. *Sport, Exercise, and Performance Psychology, 10*(1), 114–132. https://doi.org/10.1037/spy0000207

Rocchi, M., Routhier, F., Latimer-Cheung, A. E., Ginis, K. A. M., Noreau, L., & Sweet, S. N. (2017). Are adults with spinal cord injury meeting the spinal cord injury-specific physical activity guidelines? A look at a sample from a Canadian province. *Spinal Cord, 55*(5), 454–459. https://doi.org/10.1038/sc.2016.181

Rogers, L. Q., Carter, S. J., Williams, G., & Courneya, K. S. (2018). In *Physical activity* (pp. 287–307). https://doi.org/10.1007/978-3-319-77432-9_15

Rosenkranz, R. R., Ridley, K., Guagliano, J. M., & Rosenkranz, S. K. (2021). Physical activity capability, opportunity, motivation and behavior in youth settings: Theoretical framework to guide physical activity leader interventions. *International Review of Sport and Exercise Psychology*, 1–25. https://doi.org/10.1080/1750984x.2021.1904434

Samdal, G. B., Eide, G. E., Barth, T., Williams, G., & Meland, E. (2017). Effective behaviour change techniques for physical activity and healthy eating in overweight and obese adults; systematic review and meta-regression analyses. *International Journal of Behavioral Nutrition and Physical Activity, 14*(1). https://doi.org/10.1186/s12966-017-0494-y

van der Scheer, J. W., Martin Ginis, K. A., Ditor, D. S., Goosey-Tolfrey, V. L., Hicks, A. L., West, C. R., & Wolfe, D. L. (2017). Effects of exercise on fitness and health of adults with spinal cord injury: A systematic review. *Neurology, 89*(7), 736–745. https://doi.org/10.1212/WNL.0000000000004224

Sezer, N. (2015). Chronic complications of spinal cord injury. *World Journal of Orthopedics, 6*(1), 24. https://doi.org/10.5312/wjo.v6.i1.24

Sterne, J., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H. Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., … Higgins, J. (2019). RoB 2: A revised tool for assessing risk of bias in randomised trials. *BMJ, 366*, l4898. https://doi.org/10.1136/bmj.l4898

Stewart, K. J., Bacher, A. C., Turner, K., Lim, J. G., Hees, P. S., Shapiro, E. P., … Ouyang, P. (2005). Exercise and risk factors associated with metabolic syndrome in older adults. *American journal of preventive medicine, 28*(1), 9–18. https://doi.org/10.1016/j.amepre.2004.09.006

Tanhoffer, R. A., Tanhoffer, A. I., Raymond, J., Hills, A. P., & Davis, G. M. (2012). Comparison of methods to assess energy expenditure and physical activity in people with spinal cord injury. *The Journal of Spinal cord Medicine, 35*(1), 35–45. https://doi.org/10.1179/2045772311Y.0000000046

Thomas, K. J., Wise, H. H., Nietert, P. J., Brown, D., Sword, D. O., & Diehl, N. (2011). Interaction with a health care professional influences change in physical activity behaviors among individuals with a spinal cord injury. *Topics in Spinal Cord Injury Rehabilitation, 17*, 94–106.

Tomasone, J. R., Arbour-Nicitopoulos, K. P., Latimer-Cheung, A. E., & Martin Ginis, K. A. (2016). The relationship between the implementation and effectiveness of a nationwide physical activity telephone counseling service for adults with spinal cord injury. *Disability & Rehabilitation, 40*(5), 527–537. https://doi.org/10.1080/09638288.2016.1261415

Tomasone, J. R., Flood, S. M., Ma, J. K., Scime, N. V., Burke, S. M., Sleeth, L., & Marrocco, S. (2018). 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. *Psychology of Sport and Exercise, 37*, 274–285. https://doi.org/10.1016/j.psychsport.2018.01.012

Tomasone, J. R., Ma, J. K., Sweet, S. N., Donkers, S. J., Cao, P., McIntyre, A., & Martin Ginis, K. A. (2022). In *Physical activity following spinal cord injury: Participation. Spinal cord injury rehabilitation evidence. Version 8.0*.

Tomasone, J. R., Wesch, N. N., Ginis, K. A. M., & Noreau, L. (2013). Spinal cord injury, physical activity, and quality of life: A systematic review. *Kinesiology Review, 2*(2), 113–129. https://doi.org/10.1123/krj.2.2.113

Vooijs, M., Alpay, L. L., Snoeck-Stroband, J. B., Beerthuizen, T., Siemonsma, P. C., Abbink, J. J., Sont, J. K., & Rövekamp, T. A. (2014). Validity and usability of low-cost accelerometers for internet-based self-monitoring of physical activity in patients with chronic obstructive pulmonary disease. *Interactive Journal of Medical Research, 3*(4), Article e14. https://doi.org/10.2196/ijmr.3056

Warms, C. A., Belza, B. L., Whitney, J. D., Mitchell, P. H., & Stiens, S. A. (2004). Lifestyle physical activity for individuals with spinal cord injury: A pilot study. *American Journal of Health Promotion, 18*(4), 288–291. https://doi.org/10.4278/0890-1171-18.4.288

Watson, P. K., Arora, M., Middleton, J. W., Quel de Oliveira, C., Heard, R., Nunn, A., Geraghty, T., Marshall, R., & Davis, G. M. (2022). Leisure-time physical activity in people with spinal cord injury-predictors of exercise guideline adherence. *International Journal of Public Health, 67*, Article 1605235. https://doi.org/10.3389/ijph.2022.1605235

WHO. (2015). *Global recommendations on physical activity for health.* Whoint [Internet]. May 14; Available from: https://www.who.int/news-room/fact-sheets/detail/physical-activity.

Williams T, L., Smith, B., & Papathomas, A. (2014). The barriers, benefits and facilitators of leisure time physical activity among people with spinal cord injury: A meta-synthesis of qualitative findings. *Health Psychology Review, 8*, 404–425. https://doi.org/10.1080/17437199.2014.898406

Williams, T. L., Ma, J. K., & Martin Ginis, K. A. (2017). Participant experiences and perceptions of physical activity-enhancing interventions for people with physical impairments and mobility limitations: A meta-synthesis of qualitative research evidence. *Health Psychology Review, 11*(2), 179–196. https://doi.org/10.1080/17437199.2017.1299027

Wilroy, J., & Knowlden, A. (2016). Systematic review of theory-based interventions aimed at increasing physical activity in individuals with spinal cord injury. *American Journal of Health Education, 47*, 163–175. https://doi.org/10.1080/19325037.2016.1158673

Wise, H., Jackson, T., Nietert, P., Brown, D., Sword, D., & Diehl, N. (2009). Home physical activity programs for the promotion of health and wellness in individuals with spinal cord injury. *Topics in Spinal Cord Injury Rehabilitation, 14*(4), 122–132. https://doi.org/10.1310/sci1404-122

Zemper, E. D., Tate, D. G., Roller, S., Forchheimer, M., Chiodo, A., Nelson, V. S., & Scelza, W. (2003). Assessment of a holistic wellness program for persons with spinal cord injury. *American Journal of Physical Medicine & Rehabilitation, 82*(12), 957–968. https://doi.org/10.1097/01.phm.0000098504.78524.e2