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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

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## Abstract

**Objectives:** To determine which behavior change techniques (BCTs) have been used within leisure time physical activity (LTPA) self-management interventions for persons with spinal cord injury (SCI), and which BCTs were effective for improving LTPA behavior and/or its antecedents. **Design:** Systematic review informed by the PRISMA guidelines. **Methods:** A comprehensive literature search was conducted using five databases. Study characteristics were extracted from included articles and intervention descriptions were coded using the BCT Taxonomy V.1. Effectiveness and maintenance of BCTs as well as the level of behavior change theory use in the design of interventions were examined within experimental studies. **Results:** Thirty-one unique studies were included, 16 of which had an experimental design. Across all 31 studies, a total of 222 BCTs were identified, representing 32 out of a possible 93 BCTs. The most commonly used BCTs related to the core components of self-management (i.e., education, training/rehearsal of psychological strategies, and social support). Examination of the 16 experimental studies revealed that the use of BCTs corresponding to core self-management components were related to significant improvements and maintenance of LTPA outcomes, regardless of the number of BCTs used. **Conclusions:** This review offers a glimpse into the mechanisms by which self-management interventions lead to behavior change; however, more research is needed to explore and evaluate other elements (e.g., theory use, tailoring, dose, mode of delivery, and provider) that may comprise effective LTPA self-management interventions for persons with SCI. **PROSPERO registration number:** CRDXXXXXXXXXXXX.

### **Highlights**

- Commonly used BCTs related to key self-management components.
- Self-management-related BCTs were associated with improvements in LTPA outcomes.
- Only 34% of possible BCTs have been used in self-management interventions.
- Theory use, tailoring, and intervention dose, mode, and provider may also impact effectiveness.

Part 1 – A systematic review of the use and effectiveness of behavior change techniques

Literature reviews have supported the association between physical activity participation and improved health (Fernhall, Heffernan, Jae, & Hedrick, 2008), physical capacity (Hicks et al., 2011), subjective well-being (Martin Ginis, Jetha, Mack, & Hetz, 2010), and quality of life (Tomasone, Wesch, Martin Ginis, & Noreau, 2013) among persons with spinal cord injury (SCI). Despite ubiquitous benefits, persons with SCI typically have extremely low rates of physical activity, specifically leisure time physical activity (LTPA; Martin Ginis, Jetha, et al., 2010; Martin Ginis, Ma, Latimer-Cheung, & Rimmer, 2016). LTPA has been defined as physical activity that people choose to do during their free time (e.g., playing sports, exercising at a gym, or walking or wheeling; Bouchard & Shephard, 1994). Given the numerous barriers to LTPA participation that persons with SCI face (Martin Ginis, Ma, Latimer-Cheung & Rimmer., 2016), it is not surprising that 50% of Canadians with SCI engage in no LTPA whatsoever (Martin Ginis, Arbour-Nicitopoulos, et al., 2010). Interventions are needed to help address these low LTPA participation rates.

The concept of self-management (SM) is crucial for ongoing LTPA participation. According to Barlow and colleagues (2002; p. 1178), SM refers to one's "ability to manage the symptoms, treatment, physical and psychosocial consequences, and lifestyle changes inherent in living with a chronic condition". SM is a "dynamic and continuous process of self-regulation" whereby the individual must monitor their condition and respond appropriately (Barlow, Wright, Sheasby, Turner, & Hainsworth, 2002). To effectively self-manage, Lorig and Holman (2003) propose that five core SM skills are needed: a) decision-making; b) appropriate resource utilization; c) forming a partnership with a health-care provider; d) taking necessary actions; and e) problem solving. Self-efficacy, or the confidence to perform a given task, is commonly

viewed as the mediator between the acquisition of these skills and the desired SM behaviors (Bandura, 1977; Marks, Allegrante, & Lorig, 2005; Taylor et al., 2014). In the context of LTPA, SM may involve acquiring skills like planning to engage in LTPA activities, linking with adapted LTPA opportunities and providers, and problem solving to overcome barriers to LTPA participation. LTPA SM requires a behavior change approach as it involves monitoring one's activity levels and enacting cognitive, behavioral and emotional responses to increase participation when necessary.

The literature on LTPA SM interventions for persons with SCI is scarce (Wolfe et al., 2012); however, an examination of general SM intervention components provides a foundation to inform LTPA SM interventions. Fortunately, SM interventions for persons with long-term conditions have been previously synthesized (Richardson et al., 2014; Taylor et al., 2014). Taylor et al. (2014) found that the most commonly reported SM intervention components among persons with long-term conditions (e.g., stroke, diabetes, etc.) included education, action planning, and social support. Recommended approaches included tailoring SM support to the individual, and enhancing communication with health care practitioners. While 14 long-term conditions were examined in this review, SCI was not included.

In a scoping review of 95 SM interventions for persons with SCI, Wolfe and colleagues (in preparation) found results similar to Taylor et al. (2014) regarding the core components of SM interventions for persons with SCI. However, Wolfe et al.'s (in preparation) search strategy was not customized to specifically capture interventions related to *physical activity* SM or behaviour change. A recent systematic review of theory-based LTPA interventions for persons with SCI provided a starting point for describing the characteristics of published interventions (Wilroy & Knowlden, 2016). However, strict inclusion criteria (e.g., theory-based interventions

only) limited the scope to only 10 articles and results were purely descriptive, providing a fairly preliminary analysis. Methods for classifying SM strategies used in the aforementioned reviews delineate broad categories (e.g., social support, self-efficacy) without explicit details of the intervention components and how they are linked to theory, making it difficult to replicate interventions, and to understand the specifics of what strategies work and *how* (i.e., the mechanisms leading to behavior change). Ideally, a comprehensive taxonomy should be used to understand the mechanisms of LTPA SM interventions.

The Behavior Change Technique Taxonomy version 1 (BCTTv1) is a tool comprised of 93 behavior change techniques (BCTs) organized into 16 hierarchies (Michie et al., 2013). BCTs, described as the intervention components related to behavior change, represent the proposed mechanisms of change, or the “active ingredients”, in an intervention. BCTTv1 addresses the limitations of previous classification systems that lack a link to theory and expands beyond the broad SM classification systems that are most often used. For example, Barlow et al. (2002) classify self-efficacy as an intervention component, whereas BCTTv1 further addresses *how* self-efficacy can be targeted using four different BCTs (i.e., *verbal persuasion about capability, mental rehearsal of successful performance, focus on past success, self-talk*; Michie et al., 2013). While the Practical Reviews in SM Support (PRISMS) taxonomy (Pearce et al., 2016) considers the behavioral basis of SM, the BCTTv1 allows for greater precision in identifying an intervention’s components and offers online training (BCTTv1: Online Training, 2017) to ensure consistent use. Using the BCTTv1 would identify components at levels that are easily replicable and linked to theory, allowing future SM interventions to build upon the most effective techniques for behavior change. Indeed, a future direction stemming from Taylor and colleagues’ (2014) synthesis was to examine SM interventions using BCTs.



Thus, the objectives of this systematic review were: (1) To identify which BCTs (through application of the BCTTv1) have been used in interventions aimed at enhancing LTPA SM among adults with SCI; and (2) To investigate which BCTs have been effective at improving LTPA SM outcomes (including both LTPA behavior, as well as antecedents for LTPA behavior). By pairing the science of SM with that of behavior change, we sought to inform the development and/or refinement of SM interventions to improve LTPA participation among adults with SCI.

### **Methods**

The protocol for this review was registered in the PROSPERO database (CRDXXXXXXXXXX) and followed the PRISMA statement (Moher, Liberati, Tetzlaff, Altman & The PRISMA Group, 2009).

#### **Literature Search Strategy and Selection**

Systematic searches of five electronic databases were conducted (MEDLINE, EMBASE, PsycINFO, CINAHL, and the Cochrane Central Register of Controlled Trials) using terms relevant to SCI, SM, physical activity, and interventions (see Table S1 for example). Search strategies were established in consultation with an experienced health sciences librarian. Searches were delimited to studies in English, human subjects, and published from 1980 to September 2017. To confirm literature saturation, four hand-searching methods were used after the full-text review: (1) four of the included articles (Arbour-Nicitopoulos, Martin Ginis, & Latimer, 2009; Brawley, Arbour-Nicitopoulos & Martin Ginis, 2013; Latimer, Martin Ginis, & Arbour, 2006; Wise et al., 2009), all of which included the three key search terms in the article titles, using the “related articles” tools in PubMed and CINAHL; (2) the same four articles were forward searched using the “cited in” tools in PubMed and CINAHL; (3) reference lists of all

included articles were scanned; and (4) table of contents of the top six journals among the included articles were hand-searched (1980 to September 2017).

**Inclusion/exclusion criteria.** Articles had to: (a) be published in a peer-reviewed journal; (b) examine interventions that had a behavioral component aimed at enhancing LTPA behavior and/or LTPA SM strategies in any setting (e.g., health care/rehabilitation, community, home); and (c) include adults ( $\geq 18$  years) with traumatic or non-traumatic SCI. For objective 1, all study designs with quantitative data related to the outcomes were included, while for objective 2, only studies using experimental and quasi-experimental designs were included.

For both objectives, exclusion criteria included: (a) studies with qualitative analyses only; (b) retrospective or case study designs (due to the potential for multiple biases and confounders); (c) editorials, commentaries, abstracts, conference abstracts/proceedings, and dissertations; (d) interventions that were not designed to enhance LTPA behavior or SM; (e) studies that included  $\leq 3$  participants with SCI; and (f) studies in which the results for the subsample of participants with SCI were not presented separately from those of other participants.

**Outcome(s) included.** The primary outcome of interest was LTPA behavior (e.g., minutes of LTPA per day, days per week of mild-, moderate- or heavy-intensity LTPA, etc.). Both objective and subjective measures of LTPA were included. Secondary outcomes included antecedents of LTPA behavior that suggest SM capacity has been developed (e.g., self-efficacy, goal setting, action planning, etc.; Taylor et al., 2014). Maintenance of outcomes beyond the intervention period was noted.

**Screening process.** The Covidence online systematic review tool was used to export, track, de-duplicate, and manage the references from the database searches. Three reviewers (AA, BB, and CC) were involved in independently screening titles and abstracts of each de-duplicated

bibliographic record. Full texts of records were then retrieved and examined independently by two reviewers according to eligibility criteria. Disagreements about article inclusion at both screening levels (title/abstract and full text) were resolved by a third reviewer, and where an agreement could not be reached, a fourth reviewer (DD) helped to resolve discrepancies.

### **Data Extraction**

The following data were extracted from each eligible full text article: (a) author, year; (b) study type; (c) country of origin; (d) study objective; (e) participant information (i.e., age, sex, baseline LTPA level) and number of participants in the intervention group and the control group, if applicable; (f) intervention characteristics (i.e., setting, dose, mode); (g) intervention descriptions (used to code the BCTs reportedly used in each study); (h) primary and secondary outcomes; (i) quantitative results; and (j) quality assessment criteria. These variables were extracted for all included studies by one reviewer (AA) and then verified by a second reviewer (EE) to reduce reviewer error and bias. Disagreements were resolved through discussion and consensus in consultation with a third reviewer (FF) where uncertainty persisted.

### **Behavior Change Technique (BCT) Coding**

Prior to data extraction, two reviewers (AA, EE) completed online training (BCTTv1: Online Training, 2017) certifying their competence in coding the content of complex behavior change interventions using the BCTTv1, and independently pilot coded four of the included studies to corroborate inter-coder agreement. The two reviewers then independently coded the description of each intervention condition within each included study. Again, where discrepancies arose (e.g., when the two reviewers coded a BCT differently, or only one reviewer coded a BCT), consensus between the two reviewers was reached by discussion, or by consulting with another reviewer (FF). When clarification of an intervention component was required to

accurately code the BCT(s), the study's corresponding author was contacted and provided with the intervention description in question, as well as the definitions of possible BCT(s).

Clarification was required for 11 studies; all study authors responded, and BCT(s) indicated were recorded.

**Coding assumptions.** Reviewers adhered to all coding assumptions included in the BCTTv1 (Michie et al., 2013). However, when an intervention description included a form of 'counselling' without any further detail, it was assumed that this component would at least provide 3.2. *social support (practical)*. To assist with the coding of studies involving social support, Wills and Shinar's (2000) descriptions of supportive functions were utilized to supplement the definitions of social support in the BCTTv1. Specifically, an intervention component that reported a form of instrumental or informational support was coded as 3.2. *social support (practical)*; a form of emotional or companionship support was coded as 3.3. *social support (emotional)*; and a form of validation was coded as 3.1. *social support (unspecified)*.

### **Behavior Change Theory Classification**

Our review protocol did not specify an examination of behavior change theory. However, to build upon a recent systematic review (Wilroy & Knowlden, 2016), as well as to provide further guidance for the design of future LTPA SM interventions, we extended our methodology beyond what was stated in our protocol. In particular, the level of behavior change theory use was extracted for objective 2 studies to examine the relationship between theory use and outcomes. Theory was operationalized as "a set of interrelated concepts, definitions and propositions that present a systematic view of events or situations by specifying relations among variables, in order to explain or predict the events or situations" (Glanz & Rimer, 2005; p. 4). According to the framework set out by Davies, Walker, & Grimshaw (2010), studies judged to

have used theory were classified as “explicitly theory-based” (i.e., the authors explicitly stated a theory and provided a direct test of one or more of the hypotheses deduced from the theory to design the study), having “some conceptual basis” (i.e., some theory was judged to be used within the study, but the study did not provide a test of any of the hypotheses deduced from the theory to design the study), or as using “individual theoretical constructs” (i.e., one or more constructs, such as self-efficacy, were examined without positioning them within a theoretical framework). Two reviewers (AA, EE) independently classified each of the included experimental studies for the theory used and level of theory use. Many studies were lacking in their description of theory which made coding challenging; thus, the authors of included experimental studies were contacted to confirm theory use. All authors, with the exception of one, responded, and their responses were coded and reported, with discrepancies noted.

### **Study Quality**

Risk of bias in each study was determined by one reviewer (AA) and verified by a second reviewer (EE). The Cochrane Collaboration tool (Higgins et al., 2011) and the Cochrane Risk of Bias Assessment Tool for Non-Randomized Studies of Interventions (Sterne, Higgins, & Reeves, 2014) were utilized to assess the risk of bias for RCTs and quasi-experimental/non-randomized designs, respectively. Disagreements were resolved through discussion and consensus.

### **Data Analysis**

**Objective 1: Use of behavior change techniques (BCTs).** Inter-coder agreement, as well as a kappa statistic ( $\kappa$ ) and an adjusted  $\kappa$  (PABAK; Byrt, Bishop, & Carlin, 1993) to account for shared bias among coders and prevalence of agreement on ‘no’ codes (Allan, Vierimaa, Gainforth, & Cote, 2017), were calculated.

BCTs were coded within comparison and experimental conditions, whereby ‘comparison condition’ referred to the intervention condition with the fewest coded BCTs, and ‘experimental condition(s)’ referred to the intervention condition(s) with the greatest number of coded BCTs. Differences in BCTs across the two conditions were examined to determine distinct BCTs (i.e., BCTs used in the experimental condition[s], but absent from the comparison condition). Across all conditions in all studies, the total, mean, standard deviation (*SD*), and percentage use of BCTs reported (i.e., number of BCTs reported vs. 93 BCTs in BCTTv1), as well as the percentage use of each BCT hierarchy (i.e., number of hierarchies reported vs. 16 hierarchies in BCTTv1), were calculated. For experimental studies, the total, mean, and *SD* of BCTs used for each condition, as well as distinct BCTs, were calculated.

**Objective 2: Effectiveness of behavior change techniques (BCTs).** Due to heterogeneity in study outcomes and the limited number of included studies, a quantitative synthesis (e.g., meta-regression) was precluded; thus, a qualitative synthesis approach was used. Number and type of distinct BCTs used in each study were compared to study results to determine whether they were related to improvements in LTPA outcomes. The total number and percentage of included studies that employed theory in their intervention, and the level of theory use, were calculated. Finally, the number and type of distinct BCTs were compared to the use of theory and reported improvements in, and maintenance of, outcomes.

## Results

### Description of Studies

Figure 1 outlines the study selection process. Of the 33 articles included, 31 unique interventions were identified as three sets of two articles described a single intervention (i.e., Wise et al. (2009) and Thomas et al. (2011); Froelich-Grobe et al. (2012) and Froehlich-Grobe et

al. (2014); Nooijen et al. (2016) and Nooijen et al. (2017)) and one article contained two distinct interventions (Latimer-Cheung et al., 2013 (study 1); Latimer-Cheung et al., 2013 (study 2)).

Supplementary Table S2 provides details of all the included studies. Fifteen studies were prospective pre-post studies, 12 were RCTs and four were quasi-experimental studies (Figure 2).

### Quality of Studies

Of the 12 RCTs, the most commonly identified types of bias deemed to be at high risk of bias were performance bias ( $n = 9$ ), other types of bias (e.g., health literacy acting as a confounder;  $n = 7$ ), and attrition bias ( $n = 5$ ). Selection bias ( $n = 10$ ) was most commonly rated as the lowest risk of bias (see Table S3). Eighteen of the 19 studies with non-randomized designs were judged to have an overall serious risk of bias, with the majority having a serious risk of bias in measurement of outcomes ( $n = 13$ ) and selection bias ( $n = 12$ ; see Table S4).

### Objective 1: Use of Behavior Change Techniques (BCTs)

Inter-coder agreement for BCT coding was 93% ( $\kappa = .95$ , PABAK = .99), considered ‘outstanding’ according to Landis and Koch (1977). Across all studies, a total of 222 BCTs<sup>(1)</sup>, representing 32 out of a possible 93 BCTs (34%), were identified. The mean number of BCTs per intervention was 7.16 ( $SD = 3.7$ ), with a range of one to 16 BCTs. Within the 16 studies that used an experimental design, a total of 78 ( $M \pm SD = 4.88 \pm 3.38$ ; range 1-10) distinct BCTs were identified. Eight of the 16 experimental studies had a comparison condition that included BCTs, with 34 ( $M \pm SD = 2.13 \pm 2.80$ ; range 0-7) BCTs identified in the comparison conditions.

Figure 2 shows the BCTs coded for each of the 31 studies. The most commonly used BCTs across all conditions included *4.1. instruction on how to perform the behavior* (74%,  $n =$

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<sup>(1)</sup> This number exceeds 93 (the total number of BCTs included in the BCCTv1) because it represents a *total count* of BCTs across all 31 interventions, counting the same BCT more than once across studies, and where applicable, across experimental and comparison groups within the same study.

23), 1.1. *goal setting (behavior)* (65%,  $n = 20$ ), 3.2. *social support (practical)* (58%,  $n = 18$ ), 9.1. *credible source* (55%,  $n = 17$ ), 1.2. *problem solving* (52%,  $n = 16$ ), and 1.4. *action planning* (42%,  $n = 13$ ). At least one BCT was identified in 13 out of the 16 possible BCT hierarchies; no BCTs were identified within the 11. *regulation*, 14. *scheduled consequences*, and 16. *covert learning* hierarchies.

### **3.4 Objective 2: Effectiveness of Behavior Change Techniques (BCTs)**

Table 1 summarizes the 16 experimental studies. Eleven and 14 studies analyzed LTPA behavior and antecedents, respectively. LTPA antecedents ranged from outcome expectations as the least common ( $n = 1$ ), to self-efficacy (e.g., task, barrier, etc.) as the most common ( $n = 7$ ).

Five studies reported the use of one distinct BCT in the experimental condition: two studies reported positive significant changes in LTPA behavior and/or its antecedents, and three studies did not. Studies reporting a combination of distinct BCTs also had mixed findings.

Fifteen studies employed theories of behavior change in their choice and design of intervention (see Table 1). Eight of the 15 studies using theory in some capacity reported significant changes in LTPA behaviour and/or antecedents, with the number of distinct BCTs coded ranging from one to nine. The remaining seven studies showed no significant improvements in LTPA outcomes. In the one study where theory was not used, a change in an outcome was observed, with 10 distinct BCTs coded.

Seven studies reported on maintenance of changes in LTPA outcomes post-intervention, all of which used theory. Three of these studies reported maintenance of positive significant changes in LTPA outcomes ranging from six to 12 months post-intervention, and used varying numbers of distinct BCTs (three to nine). Four studies using one, two, five, and six distinct BCTs did not report significant changes and maintenance in LTPA outcomes.



## Discussion

### Objective 1: Use of Behavior Change Techniques (BCTs)

This review identified the BCTs that have been used in interventions designed to enhance LTPA SM among persons with SCI, demonstrating that it is feasible to apply the BCTTv1 to characterize the “active ingredients” of behavior change within SM interventions. Five of the most commonly used BCTs identified within this review relate to components that are most commonly-reported and suggested to be necessary for long-term SM in previous reviews for persons with SCI (Wolfe et al., in preparation) and other chronic conditions (Taylor et al., 2014). Specifically, the most commonly reported BCT, *4.1. instruction on how to perform the behavior*, is conceptually similar to the core SM components of education (Taylor et al., 2014) and information about SM of the condition (Wolfe et al., in preparation). The BCTs *1.1. goal setting (behavior)*, *1.2. problem solving*, and *1.4. action planning* involve the training and/or rehearsal of psychological strategies, and the BCT *3.2. social support (practical)* – advising on, arranging, or providing practical help for performance of the behavior – are directly related to social support for SM. Although an approach to intervention design and not a BCT, an additional recurring component of SM interventions seen in the literature is tailoring of SM support to the individual (Taylor et al., 2014). The reviewers noted that tailoring was used within 12 of the included studies. Overall, these findings suggest that the core components of SM interventions are, indeed, commonly used within existing interventions aimed at enhancing LTPA SM among persons with SCI.

While the most commonly used BCTs relate to the core components of SM, interventions focused on LTPA SM are only utilizing 32 of the 93 possible BCTs. Thus, an opportunity exists for the development of novel interventions that incorporate currently underutilized BCTs, such

as 1.7. *reviewing outcome goals*, 12.4. *distraction*, and 13.2. *framing/reframing*, all of which relate to training and/or rehearsal of psychological strategies and may therefore prove effective in enhancing LTPA SM. Further, the identified BCTs represented only 13 of the possible 16 BCTTv1 hierarchies. Given that ongoing monitoring is critical to SM (Barlow et al., 2002), a potentially untapped BCTTv1 hierarchy for LTPA SM among persons with SCI is *regulation*. In particular, within this hierarchy, the BCT 11.2. *reducing negative emotions* relates to stress management, and has been used in interventions that involve training/rehearsal for psychological strategies (Pearce et al., 2016; Taylor et al., 2014). Given that barriers to LTPA participation among persons with a physical disability include negative mood, anxieties, and fears related to physical activity (Martin Ginis et al., 2016), this BCT may be useful in future LTPA SM interventions for persons with SCI.<sup>(2)</sup>

## **Objective 2: Effectiveness of Behavior Change Techniques (BCTs)**

As seen in a previous review examining BCTs for LTPA behavior (Taylor, Conner, & Lawton, 2012), the number of distinct BCTs did not make a difference in regards to improvements in, and maintenance of, LTPA outcomes among persons with SCI; rather, utilization of distinct BCTs related to the core components of SM seemed to be more important. Examination of distinct BCTs across the experimental studies revealed that the three distinct BCTs relating to the core SM components of training/rehearsal of psychological strategies (i.e., 1.2. *problem solving*, 1.5. *review behavior goal[s]*) and education (i.e., 5.1. *information about health consequences*) were related to positive LTPA outcomes, and thus, should be considered in

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<sup>(2)</sup> For example, an intervention may involve openly discussing concerns associated with LTPA and subsequently providing strategies and encouragement to assist the individual in overcoming those concerns. Moreover, this BCT may be especially effective in combination with appropriate tailoring to a person's readiness for behavior change. That is, the interventionist could adopt different strategies to support the individual's LTPA concerns depending on whether or not they have formed an intention to be active or they are regularly active (Martin Ginis et al., 2013).

future interventions. Both training/rehearsal of psychological strategies and education have been identified as important elements of SM interventions for persons with chronic conditions (Taylor et al., 2014; Wolfe et al., in preparation) and may be useful in alleviating LTPA barriers commonly-faced among persons with SCI (Martin Ginis et al., 2016).

However, when BCTs relating to training/rehearsal of psychological strategies (*1.1. goal setting (behavior)*, *1.2. problem solving*, or *1.4. action planning*) and education (*4.1. instruction on how to perform the behavior*, or *5.1. information about health consequences*) were used in combination with other BCTs, there were mixed findings for LTPA outcomes. Also related to education, the BCTs *5.3. information about social and environmental consequences* and *6.1. demonstration of the behavior* did not correspond with any improvements in LTPA outcomes. Further, BCTs relating to other core SM components, such as social support (*3.1. social support [unspecified]*, *3.2. social support [practical]*, or *3.3. social support [emotional]*) corresponded with positive improvements in LTPA outcomes in some cases while not in others. The only BCT used in combination that consistently corresponded with improvements in LTPA outcomes was *1.7. review behavior goal(s)*, which is conceptually similar to training and/or rehearsal of psychological strategies (Taylor et al., 2014; Wolfe et al., in preparation), and the core premise that monitoring and regulation are required for SM (Barlow et al., 2002). Thus, future LTPA SM interventions for persons with SCI may benefit from including *1.7. review behavior goal(s)*, whereas the benefit of other BCTs related to training/rehearsal and education is less certain.

Self-efficacy empowers individuals to self-manage; it is needed to enable execution of LTPA, and is thus an antecedent of LTPA behaviour (Taylor et al., 2014). A measure of self-efficacy was included in seven (Arbour-Nicitopoulos et al., 2017, 2009; Block et al., 2010; Foulon & Martin Ginis, 2013; Latimer et al., 2006; Zahl et al., 2008; Zemper et al., 2003) of the

experimental studies. Two (Arbour-Nicitopoulos et al., 2009; Latimer et al., 2006) of these studies also measured LTPA behavior and found improvements in both self-efficacy and behavior. Both studies included distinct BCTs that relate to the common core components of SM interventions discussed above. However, none of these seven studies included BCTs from BCTTv1 that are proposed to directly target self-efficacy: the self-belief hierarchy, which includes *15.1. verbal persuasion about capability*, *15.2. mental rehearsal of successful performance*, *15.3. focus on past success*, and *15.4. self-talk*. These findings suggest that self-efficacy for LTPA may be indirectly targeted by BCTs relating to the core components of SM in addition to the BCT hierarchy of self-belief. For example, in the three studies where increases in self-efficacy were observed, the distinct BCTs used (relating to training/rehearsal of psychological strategies) were important for SM and therefore performance of LTPA behavior. Increases in behaviour may have provided participants with mastery experience which may have increased and strengthened self-efficacy (Bandura, 1977). Future SM studies should examine the independent and combined effects of BCTs that directly and indirectly target self-efficacy.

Of the seven studies that reported maintenance in outcomes, six (Arbour-Nicitopoulos et al., 2017; Block et al., 2010; Froehlich-Grobe et al., 2012, 2014, Nooijen et al., 2016, 2017; Thomas et al., 2011; van der Ploeg et al., 2007; Wise et al., 2009) incorporated distinct BCTs that relate to the common core components of SM interventions (e.g., *1.1 goal setting (behavior)* and *3.2. social support [practical]*), and used a differing number of distinct BCTs (two (Arbour-Nicitopoulos et al., 2017) to nine (Nooijen et al., 2016, 2017)). Consequently, neither the use of distinct BCTs that relate to core components of SM interventions nor the number of distinct BCTs used were able to fully explain what leads to sustained improvements. These findings suggest that examination of the presence of BCTs alone do not sufficiently determine

effectiveness and maintenance of LTPA SM interventions for persons with SCI; other intervention factors may also influence the impact of the intervention.

Theory use has been encouraged for decades to maximize behavior change intervention impact (e.g., Brawley, 1993). The current review found that theory was used in 15 of 16 experimental studies, a promising finding suggesting that theory use is standard practice, as has been previously recommended (Martin Ginis et al., 2011), among researchers aiming to enhance LTPA among persons with SCI. However, the impact of theory use could not be teased out, as eight studies reported improvements in outcomes while seven studies did not. Therefore, theory use alone cannot fully account for the effectiveness and maintenance of LTPA SM interventions.

Other factors may also influence an intervention's impact. For example, intervention dose (i.e., contact frequency, session duration, and/or intervention length) has been suggested to be positively related to LTPA behavior (Rabin, Brownson, Kerner, & Glasgow, 2006), including among persons with SCI (Tomasone, Arbour-Nicitopoulos, Latimer-Cheung, & Martin Ginis, 2016). The studies included within this review largely omitted reporting intervention dose or did not provide sufficient information to calculate dose, notwithstanding the underlying complexities in sufficiently characterizing dose. For the few studies that did report dose, the total contact time ranged from 40 minutes (van der Ploeg et al., 2007) to 24 hours (Zahl et al., 2008) providing little direction on the ideal intervention dose for enhancing LTPA SM. Future studies should strive to clarify the moderating role of the dose of the BCTs used within interventions (Proctor, Powell, & McMillen, 2013). Intervention delivery mode and provider may also play a moderating role on LTPA outcomes. Previous studies (e.g., Letts et al., 2011) have highlighted that, among persons with SCI, the preferred delivery modes for obtaining LTPA information are passive sources (e.g., internet, DVDs, newsletters), while the preferred providers are peers and

trained health service providers. We attempted to extract delivery mode and provider from the included studies, but this information was not always clearly stated within the publication. Regardless, it is evident that there may be other factors that influence intervention effectiveness above and beyond which BCTs are used. This conclusion is in line with Ogden (2016) who argues that by simplifying an intervention into BCTs, the variability within intervention participants (e.g., level and severity of SCI), intervention providers (e.g., profession, training, and experience in SM management approaches), and even theories of behavior change is ignored. Overall, coding using BCTs may be limiting as it does not provide the full picture of *how* BCTs should be operationalized within an intervention.

Ultimately, LTPA SM interventions need to be implemented in the “real-world” to maximize their potential benefit for persons with SCI. From our current analysis, it is unclear whether the interventions described are transferable to practice settings. The use of study design and evaluation tools, such as the RE-AIM Framework (Glasgow, Vogt, & Boles, 1999) and the PRagmatic–Explanatory Continuum Indicator Summary (PRECIS-2 (Loudon et al., 2015)) tool, would help determine the generalizability and applicability of these interventions. Using these tools, a secondary analysis of the current review was conducted to examine the degree to which the included studies reported factors that facilitate intervention translation into practice (Burke et al., submitted).

### **Strengths and Limitations**

To our knowledge, this is the first study to examine BCTs in LTPA SM interventions for persons with SCI. Certain BCTs, specifically those relating to core SM components, have been identified as potentially yielding improvements in, and maintenance of, LTPA participation

among individuals with SCI. Further, rigorous systematic review methods (Moher et al., 2009), included the use of two reviewers for all data screening, extraction, and coding processes.

Several limitations relating to coding in this review should be noted. First, a coding assumption was that counselling interventions ( $n = 9$ ) would at least involve *social support (practical)* which may have resulted in an under-representation of other BCTs used. Second, 11 authors were contacted to obtain more information about their intervention description in order to code BCT(s). Six of the 11 authors suggested an alternative BCT to the one suggested or stated that the singular component incorporated multiple BCTs; if we had followed up with the authors of all included studies to confirm all coded BCTs, it is possible that other BCTs may have been suggested which would ultimately influence our findings. Publication bias was also evident when determining theory use. Based on reviewer coding, 11 experimental studies were deemed to have used theory; however, following correspondence with study authors, 15 studies reportedly used theory. Similarly, it was not possible to extract dose, mode and provider characteristics from all studies based on the level of detail reported in the publication. Together, these limitations indicate that coding is reliant on reported content, a previously discussed challenge of coding BCTs in interventions (Presseau et al., 2015). Accordingly, authors should strive to include more specific and thorough intervention descriptions to ensure that the described components accurately reflect the intervention delivered. Further, researchers examining BCTs and other intervention components should contact study authors to confirm that the appropriate details reflecting intervention content have been accurately coded.

A number of limitations relating to the evidence base for this review should also be considered. The majority of included studies were judged to be at a high risk of bias, so results should be interpreted in light of the low-quality ratings; however, high risk is often intrinsic to

the nature of LTPA SM interventions. Many studies use a self-referral process for participant selection, whereby participants volunteer based on interest rather than undergo randomization. Also, LTPA outcomes are typically self-reported, putting studies at high risk of “measurement of outcome”; yet, the most reliable measure of LTPA behavior that currently exists for persons with SCI is the self-reported Physical Activity Recall for Persons with SCI (Tanhoffer, Tanhoffer, Raymond, Hills, & Davis, 2012), and LTPA antecedents are cognitive in nature and rely on self-report scales to be measured. Further, incomplete outcome data and selective reporting are the most difficult items to assess using the Cochrane Collaboration’s tool for assessing risk of bias in RCTs (Higgins et al., 2011), suggesting that the utility of the tool may be lacking in these domains. Consequently, the results of the included studies may be overestimating the effects of the corresponding interventions, which may in turn overestimate of the importance of using BCTs that relate to core SM components. Finally, due to heterogeneity in study outcomes and the limited number of included studies, the use of meta-regression to determine the specific contributions of each distinct BCT on intervention effectiveness was precluded.

### **Conclusion**

This study aimed to determine which BCTs have been used within LTPA SM interventions for persons with SCI, and which BCTs were effective in improving LTPA behavior and its antecedents. The use of BCTs corresponding to core SM components were related to significant improvements and maintenance of LTPA outcomes, regardless of the number of BCTs used. However, theory use, intervention dose, mode and provider, as well as tailoring these to the individual, may be important to consider in addition to the selection of BCTs.



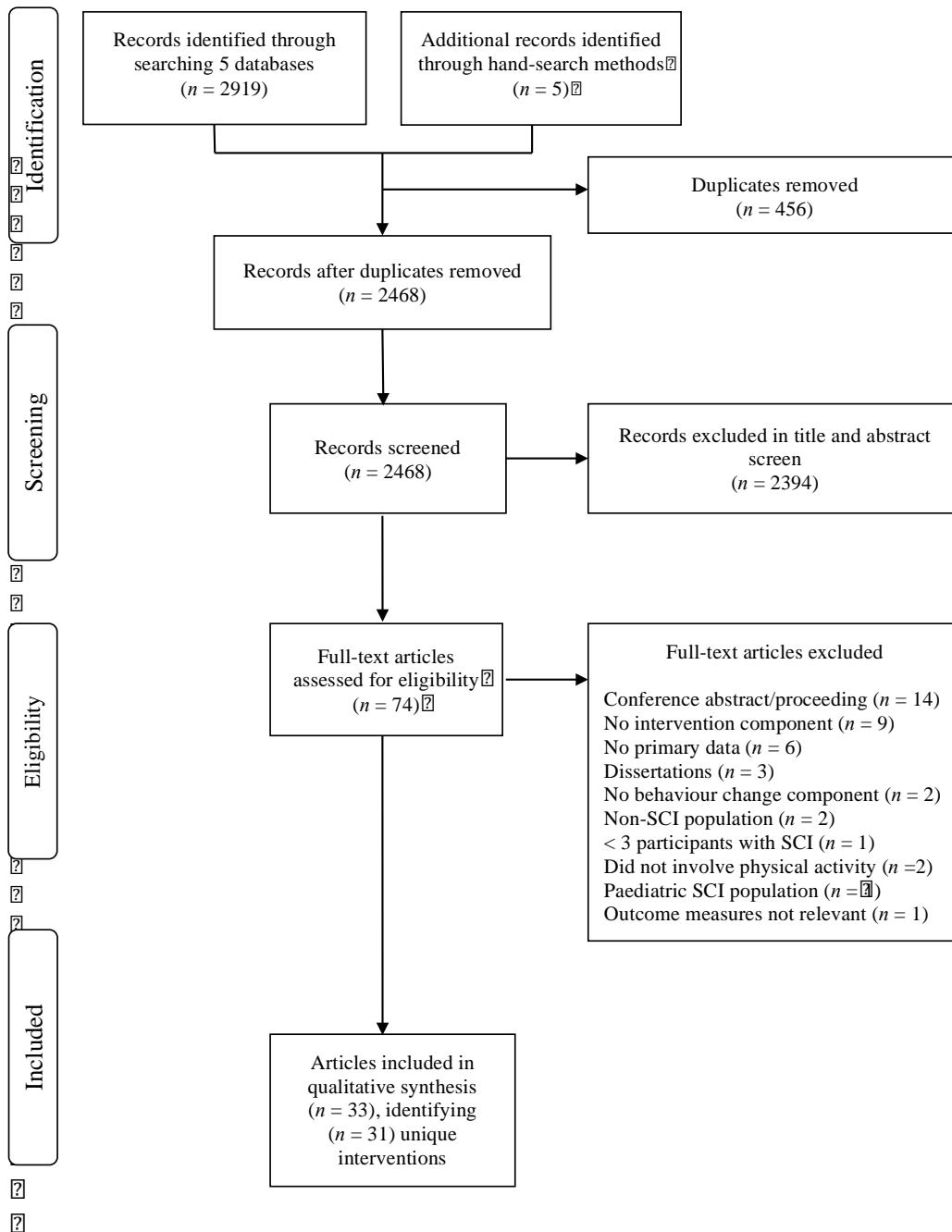


Figure 1. Flowchart of article selection process.



Table 1

*Examination of Experimental Studies Included in the Systematic Review*

Study	Distinct BCTs	Behavior change theory or constructs (level of use)	Intervention length <sup>a/</sup> Intervention duration <sup>b/</sup> Evaluation time points	Results						
				Primary outcomes (LTPA behavior)	Secondary outcomes (Antecedents to LTPA behavior)	Maintenance (LTPA behavior and/or antecedents)				
Arbour-Nicitopoulos (2009)	1.2	Health Action Process Approach (ETB)*	10 weeks; 60-90 minutes; Baseline, 5 weeks, and post-intervention	<ul style="list-style-type: none"> <li>• + PARA-SCI (shortened version)</li> </ul>	<ul style="list-style-type: none"> <li>• Ø Intentions</li> <li>• + General barriers SE</li> <li>• + Facility barriers SE</li> <li>• + Scheduling SE</li> </ul>	NM				
Arbour-Nicitopoulos (2017)	5.1 5.6	Health Action Process Approach (ETB)*	1 day; unable to determine; Baseline, 24 hours post-baseline, 1-week post-intervention, 1-month post-intervention	<ul style="list-style-type: none"> <li>• Ø LTPAQ-SCI<sup>1-week</sup></li> </ul>	<ul style="list-style-type: none"> <li>• Ø Intentions</li> <li>• Ø Task SE</li> <li>• Ø Barrier SE</li> <li>• Ø Outcome expectancies</li> </ul>	<ul style="list-style-type: none"> <li>• Ø LTPAQ-SCI<sup>1-month</sup></li> <li>• Ø Action planning<sup>1-week, 1-month</sup></li> <li>• Ø Intentions<sup>1-week, 1-month</sup></li> <li>• Ø Task SE<sup>-week, 1-month</sup></li> <li>• Ø Barrier SE<sup>1-week, 1-month</sup></li> </ul>				
Bassett-Gunter (2013)	5.1	Protection motivation theory (SCB), Extended parallel process model (SCB)	2 days; unable to determine; Baseline and post-intervention	NM	<ul style="list-style-type: none"> <li>• + Disease risk group vulnerability</li> <li>• + Psych health risk group vulnerability</li> </ul> <table border="0" style="margin-left: 20px;"> <tr> <td style="text-align: center;">E1</td> <td style="text-align: center;">E2</td> </tr> <tr> <td> <ul style="list-style-type: none"> <li>• Ø Disease risk group response efficacy</li> <li>• Ø Psyc health risk group response efficacy</li> <li>• Ø Intentions</li> <li>• + SE</li> </ul> </td> <td> <ul style="list-style-type: none"> <li>• Ø Disease risk group response efficacy</li> <li>• + Psyc health risk group response efficacy</li> <li>• + Intentions</li> </ul> </td> </tr> </table>	E1	E2	<ul style="list-style-type: none"> <li>• Ø Disease risk group response efficacy</li> <li>• Ø Psyc health risk group response efficacy</li> <li>• Ø Intentions</li> <li>• + SE</li> </ul>	<ul style="list-style-type: none"> <li>• Ø Disease risk group response efficacy</li> <li>• + Psyc health risk group response efficacy</li> <li>• + Intentions</li> </ul>	NM
E1	E2									
<ul style="list-style-type: none"> <li>• Ø Disease risk group response efficacy</li> <li>• Ø Psyc health risk group response efficacy</li> <li>• Ø Intentions</li> <li>• + SE</li> </ul>	<ul style="list-style-type: none"> <li>• Ø Disease risk group response efficacy</li> <li>• + Psyc health risk group response efficacy</li> <li>• + Intentions</li> </ul>									
Block (2010)	1.1 2.1 3.2 3.3 4.1 8.1	Goal orientation theory (SCB)*, Disability studies framework of empowerment (SCB)*	5 months; unable to determine; Baseline, post-intervention, and 6- and 12-months post-intervention	NM	<ul style="list-style-type: none"> <li>• + SE</li> </ul>	<ul style="list-style-type: none"> <li>• ND SE</li> </ul>				

	E1	E2			NM	E1	E2	NM
Foulon (2013)	5.1	6.1	Health Action Process Approach (ETB)*	7 days; 30 minutes; Baseline and post-intervention		<ul style="list-style-type: none"> <li>• Ø Health risk perceptions</li> <li>• Ø Mental health risk perceptions</li> <li>• Ø Outcome expectations</li> <li>• Ø Moderate aerobic SE</li> <li>• Ø Heavy aerobic SE</li> <li>• Ø Task SE</li> <li>• Ø Intentions</li> <li>• Ø Action plans</li> <li>• Ø Coping plans</li> <li>• Ø Action control</li> <li>• Ø Self-regulation</li> </ul>	<ul style="list-style-type: none"> <li>• Ø Action plans</li> <li>• Ø Coping plans</li> <li>• Ø Action control</li> <li>• Ø Self-regulation</li> <li>• Ø Barrier SE</li> <li>• Ø Recovery SE</li> </ul>	
Froehlich-Grobe (2004)	1.2 1.4 2.1 2.3 3.2 3.3 4.1 5.1 10.9		Social cognitive theory (SCB)*, Relapse prevention theory (SCB)*	6 months; unable to determine; Baseline and post-intervention	<ul style="list-style-type: none"> <li>• ND Self-report total activity min</li> <li>• ND Self-report cardiovascular activity min</li> <li>• ND Self-report strengthening activity min</li> </ul>	<ul style="list-style-type: none"> <li>• Ø Number of secondary conditions</li> </ul>		NM
Froehlich-Grobe (2012, 2014)	1.1 1.2 1.4 1.5 2.4 3.1 3.2 5.1 9.1		Social cognitive theory (SCB)*, Relapse prevention theory (SCB)	6 months; unable to determine; Weekly for 52 weeks	<ul style="list-style-type: none"> <li>• ND Self-report aerobic exercise (min per week)</li> <li>• ND Self-report aerobic exercise (days per week)</li> <li>• ND Self-report resistance exercise (days per week)</li> </ul>	NM		<ul style="list-style-type: none"> <li>• + Self-report aerobic exercise (min per week)<sup>Over 52 weeks</sup></li> <li>• + Self-report aerobic exercise (days per week)<sup>Over 52 weeks</sup></li> <li>• + Self-report resistance exercise (days per week)<sup>Over 52 weeks</sup></li> </ul>

Kosma (2005)	1.1	Transtheoretical model (ETB)	4 weeks; unable to determine; Baseline and 1-month post-intervention	• Ø PASIPD (LTPA scores only)		• Ø Stage-of-change		NM		
	1.2									
	1.9									
	3.1									
	5.3									
	7.1									
	9.1									
Latimer (2006)	1.1	Theory of Planned Behavior and Implementation Intentions (ETB)*	8 weeks; unable to determine; Baseline and post-intervention	• + PARA-SCI (duration) <sup>Post-intervention</sup> • Ø PARA-SCI (frequency) <sup>Post-intervention</sup>		• + Intentions <sup>Post-intervention</sup> • + Scheduling SE <sup>At week 5</sup> • Ø Perceived behavioral control <sup>Post-intervention</sup> • Ø Barrier SE <sup>At week 5</sup>		NM		
	1.4									
	1.5									
Nooijen (2016, 2017)	1.1	Transtheoretical Model (ITC)*	8 months; unable to determine; 2 months pre-rehabilitation discharge, at discharge, 6 months post-discharge, and 12 months post-discharge	• + Wheeled PA (min/day) <sup>At 6 months</sup> • + PASIPD <sup>At 6 month</sup>		• Ø Social participation <sup>At 6 months</sup> • Ø Quality of life <sup>At 6 months</sup>		• + Wheeled PA (min/day) <sup>At 12 months</sup> • + PASIPD <sup>At 12 months</sup> • + Social participation <sup>At 12 months</sup> • Ø Quality of life <sup>At 12 months</sup>		
	1.2									
	1.4									
	2.2									
	2.3									
	5.1									
	9.1									
	12.1									
	12.5									
Rimmer (2013)	E1	N/A	9 months; unable to determine; Baseline and post-intervention	E1	E2	E1	E2	NM		
	1.1			1.1	• Ø PADS (aerobic exercise)	• Ø PADS (aerobic exercise)	• Ø Barriers to Physical Activity and disability survey score			• Ø Barriers to Physical Activity and disability survey score
	1.2			1.2						
	1.4			1.4						
	2.1			2.1	• Ø PADS (strength exercise)	• Ø PADS (strength exercise)				
	2.2			2.2						
	2.3			2.3						
	3.2			3.2	• Ø PADS (total exercise)	• + PADS (total exercise)				
	4.1			4.1						
	8.7			8.7						
van der Ploeg(2007)	E1	Physical activity for people with a disability model (ETB)	E1: 12 weeks, 40 min, E2: 14 weeks; 140 min; 1 year pre-rehabilitation, baseline and 1 year post-rehabilitation	E1	E2	E1	E2	E1	E2	
	1.1			1.1	• ND PASIPD	• ND PASIPD	• ND Sport participation	• ND Sport participation	• Ø PASIPD	• Ø PASIPD
	1.2			1.2					• Ø Sport participation	• + Sport participation
	2.1			2.1			• ND Sport score	• ND Sport score	• Ø Sport score	• Ø Sport score
	3.2			3.2			• ND Meeting PA rec	• ND Meeting PA rec	• Ø Meeting PA rec	• + Meeting PA rec
	4.1			4.1						
	10.3			10.3						

Wickham (2000)	8.1	Attitude (ITC), Motivation (ITC)	2 days; unable to determine; Baseline and post-intervention	NM	<ul style="list-style-type: none"> <li>• Ø Intellectual leisure motivation</li> <li>• Ø Social leisure motivation</li> <li>• Ø Competence leisure motivation</li> <li>• + Stimulus-avoidance leisure motivation</li> <li>• Ø Cognitive attitudes</li> <li>• Ø Affective attitudes</li> <li>• Ø Behavioral attitudes</li> </ul>	NM
Wise (2009), Thomas (2011)	1.1 1.2 2.2 3.2 3.3	Health Belief Model (SCB)*, Transtheoretical Model (SCB)*, Social Learning Model (SCB)*, Relapse Prevention Model (SCB)*	3 months; unable to determine; Baseline, post-intervention, and 6 months	<ul style="list-style-type: none"> <li>• Ø Self-report log (min per week)<sup>Post-intervention</sup></li> <li>• Ø Self-report log (days per week)<sup>Post-intervention</sup></li> </ul>	NM	<ul style="list-style-type: none"> <li>• Ø Self-report log (min per week)<sup>At 6 months</sup></li> <li>• Ø Self-report log (days per week)<sup>At 6 months</sup></li> </ul>
Zahl (2008)	13.4	Self-efficacy Theory (ETB)*	8 weeks; 24 hours; Baseline, post- and 1-month post-intervention	NM	<ul style="list-style-type: none"> <li>• ND Active living</li> <li>• ND SE in active living</li> </ul>	<ul style="list-style-type: none"> <li>• ND Active living</li> <li>• ND SE in active living</li> </ul>
Zemper (2003)	1.1 1.2 1.4 1.5	Stuifbergen model (ETB)*, Quality of life model (SCB)*	7 months; unable to determine; Baseline, 14 weeks, and post-intervention	<ul style="list-style-type: none"> <li>• ND HPLP-II PA subscale</li> <li>• ND PADS exercise activity subscale</li> <li>• ND PADS leisure activity subscale</li> </ul>	<ul style="list-style-type: none"> <li>• ND Health-related SE</li> <li>• ND Stress management techniques</li> </ul>	NM

*Note.* Sample size: E1 = first experimental condition; E2 = second experimental condition. Behavior change theory and/or construct level of use: ETB = explicitly theory based; SCB = some conceptual basis; ITC = individual theoretical construct; N/A = theory was judged not to be used within choice and design of intervention. NM = outcome not measured; ND = analysis of outcome measure not determined. Statistical significance: + = statistically significant relationship ( $p < .05$ ) relative to the comparison condition, Ø = no statistically significant relationship found relative to the comparison condition. LTPA Measures Abbreviations: PARA-SCI = Physical Activity Recall Assessment for People with Spinal Cord Injury (Martin Ginis, Latimer, Hicks, & Craven, 2005); LTPAQ-SCI = Leisure-Time Physical Activity Questionnaire for Adults with SCI (Martin Ginis & Latimer, 2007); HPLP-II PA Subscale = Health Promoting Lifestyle Profile-II Physical Activity Subscale (Walker, Sechrist, & Pender, 1987); PADS = Physical Activity with Disability Survey (Rimmer, Riley, & Rubin, 2001); PASIPD = Physical Activity Scale for Individuals with Physical Disabilities (Washburn, Zhu, McAuley, Frogley, & Figoni, 2002). References for LTPA measures are available in Supplementary Materials (Item S5). Secondary outcomes: PA = physical activity; Psyc = psychological; rec = recommendation; SE = self-efficacy. Several studies included multiple intervention groups, for more information refer to Table S2. Distinct BCTs refers to BCTs used in the experimental condition of a study, but absent from the study's comparison condition. For results, primary and secondary outcomes are reported as differences over the intervention period between experimental and comparison groups, unless otherwise noted. Maintenance is reported as differences over the maintenance period between experimental and comparison groups.

<sup>a</sup> Intervention length excludes follow up/maintenance periods. <sup>b</sup> Intervention duration refers to the total intervention hours.

\*Discrepancy between theory use reported in publication and follow-up correspondence with author.

## Supplementary Materials

Table S1

#	Search	# Results
1	(tetraplegia.mp. or exp Quadriplegia/) OR (exp paraplegia/ or paraplegia.mp.) OR Spinal Cord Compression/ OR Spinal Cord/ OR Spinal Fractures/ OR Spinal Cord Injuries/ OR Cervical Vertebrae/ OR Thoracic Vertebrae/ OR Lumbar Vertebrae/ OR Sacral Vertebrae/ OR Spinal Injuries/ OR spinal cord injur*.mp.	203039
2	(self-management.mp. or Self Care/) OR (Behavior Therapy/ or Behavior/ or Behavior Control/ or Health Behavior/ or Health Promotion/ or behavior?r.mp. or behavior?r change.mp. or Motivational interviewing.mp. or Motivational Interviewing/) OR (Self-monitoring.mp.) OR (Social support/ or social support.mp. or practical support.mp. or Peer Group/ or Counseling/ or Peer support.mp. or Mentors/ or Peer mentoring.mp. or coping.mp.) OR (Health Planning/ or Action plan*.mp.) OR (Feedback.mp. or Feedback/) OR (Training.mp.) OR ("Practice (Psychology)"/ or Rehearsal.mp.) OR (Problem solving.mp. or Problem Solving/) OR (Goals/ or Goal setting.mp.) OR (Cognitive Therapy/ or Cognitive restructuring.mp.) OR (Cues.mp. or Cues/ or prompts.mp.) OR (Health Education/ or Education/ or Education.mp.) OR (Reward/ or Reward.mp.) OR (Self-belief.mp. or self-talk.mp.) OR (Motivation/ or Incentive.mp.) OR (Self-regulation.mp. or Social Control, Informal/ or Self Concept/)	2094846
3	(Physical fitness/ or physical fitness.mp.) OR (Exercise therapy/ or exercise/ or exercise therapy.mp. or exercise.mp.) OR (Sports/ or Sports.mp.) OR (Motor Activity/ or Physical activity.mp.) OR ("Physical Education and Training"/ or Training.mp. or physical education.mp.)	662408
4	(Healthy People Programs/ or Self-Evaluation Programs/ or Program.mp.) OR (Intervention Studies/ or Intervention.mp.) OR (Health Promotion/ or promotion.mp.) OR (initiative.mp.) OR (strategy.mp.)	1115165
5	1 AND 2 AND 3 AND 4	932

*Sample Search Strategy for MEDLINE (Ovid).*

*Notes.* \* = all variations of word endings (i.e., comput\* finds computer, computing, etc.).

Table S2

*Summary of Studies Included in the Systematic Review*

	Study, Country	Study design, Sample size	Purpose	Intervention Setting	Mode of Delivery
Prospective pre-post study designs ( <i>n</i> = 15)	Arbour-Nicitopoulos (2014) Canada	Prospective pre-post n = 53; 32	To assess the individual-level impact of a previously tested telephone-based counseling intervention among adults within the SCI community by using the first 2 components of the RE-AIM framework	Home-based	Telephone
	Bassett (2011) Canada	Prospective pre-post n = 62; 62	To examine changes in perceived risk for disease following an individualized health information intervention and to examine changes in perceived risk for disease as a predictor of changes in LTPA	Home-based	Telephone Mail
	Brawley (2013) Canada	Prospective pre-post n = 13; 10	To test the efficacy and feasibility of a group-mediated cognitive-behavioral training intervention for increasing self-managed LTPA among people with SCI who are already somewhat active	Unspecified	Telephone Face-to-face meetings Group meetings
	de Oliveira (2016) Australia and New Zealand	Prospective pre-post n = 85; 40	To determine the effects of the Spinal Cord Injury and Physical Activity in the Community intervention on LTPA and associated outcomes among participants with SCI	Community Fitness centres	Face-to-face meetings Telephone
	Gainforth (2013) Canada	Prospective pre-post n = 104; 66	To examine the reach and effectiveness of an event-based knowledge mobilization initiative that used interpersonal communication to disseminate the guidelines to people with SCI	Unspecified	Face-to-face meetings Group meetings



Lai (2016) United States	Prospective pre-post n = 4; 4	To test the feasibility of a remotely delivered home exercise program for individuals with SCI as determined by (1) implementation of the intervention in the home; (2) exploration of the potential intervention effects on aerobic fitness, physical activity behavior, and subjective well-being; and (3) acceptability of the program through participant self-report	Home-based	Face-to-face meeting Web-based platform
Latimer-Cheung(2013) study 1 Canada	Prospective pre-post n = 7; 7	To examine the effects of a single, telephone-based counseling session on self-regulatory efficacy, intentions, and action plans for LTPA	Home-based	Telephone
Latimer-Cheung(2013) study 2 Canada	Prospective pre-post n = 12; 10	To examine the effects of a home-based strength- training session, delivered by a peer and a fitness trainer, on strength-training task self-efficacy, intentions, action plans, and behavior	Home-based	Face-to-face meetings
Myers (2012) United States	Prospective pre-post n = 26; 10	To determine the influence of a multidisciplinary risk management program on cardiovascular disease risk in persons with SCI	Medical centre- and home-based	Telephone Face-to-face meetings
Pelletier (2014) Canada	Prospective pre-post n = 17; 15	To evaluate the efficacy of referral from a health-care provider to regular exercise combined with counseling support following discharge from inpatient or outpatient SCI rehabilitation	Self-selected by participants	Telephone
Piatt (2012) United States	Prospective pre-post n = 3; 3	To examine the effects of a recreation intervention designed to foster self-efficacy and self-affirmation on increasing active living scores individuals with a SCI	Community-based	Face-to-face meetings
Radomski (2011)	Prospective pre-post	To evaluate the feasibility and impact of a 12-week community-based program for	Community- and home-based	Face-to-face meetings Group meetings

	United States	n = 13; 10	wellness and weight management on weight control and fitness of people with SCI		DVD/video
	Sheehy (2013)	Prospective pre-post	To determine the effects of a nurse-coached exercise program for people with tetraplegic SCI on muscle strength, quality of life, and self-efficacy	Community-based	Face-to-face meetings
	United States	n = 10; 10			
	Tomasone (2016)	Prospective pre-post	The purpose of this study was to explore the implementation correlates of change in LTPA intentions and behavior in the second phase of Get in Motion	Home-based	Telephone
	Canada	n = 46; 25			
	Warms (2004)	Prospective pre-post	To evaluate the acceptability and feasibility of a lifestyle physical activity program for people with SCI	Home-based	Telephone Face-to-face meetings Printed materials
	United States	n = 17; 16			
Experimental study designs (n = 16)	Arbour-Nicitopoulos (2009)	RCT	To examine the effects of action planning only (C) and action and coping planning (E) on LTPA and self-efficacy in exercise among persons with SCI	Home-based	Telephone
	Canada	n <sub>E</sub> = 22; 18 n <sub>C</sub> = 22; 20			
	Arbour-Nicitopoulos (2017)	RCT	To evaluate the efficacy of the SCI Get Fit Toolkit delivered online on theoretical constructs and moderate-to-vigorous physical activity among adults with SCI	Home-based	Web
	Canada	n <sub>E</sub> = 42; 35 n <sub>C</sub> = 48; 42			
	Bassett-Gunter (2013)	RCT	To examine the relative effectiveness of chronic disease and psychological health risk information combined with gain (E1) versus loss-framed (E2) LTPA messages for changing perceived personal risk, LTPA response-efficacy, and LTPA intentions among persons with SCI	Home-based	E-mail
	Canada	n <sub>E1</sub> = 32; 32 n <sub>E2</sub> = 34; 34 n <sub>C</sub> = 28; 28			
	Block (2010)	Quasi-experimental	To assess the influence of a health promotion and capacity building program on self-efficacy	Community-based	Telephone Face-to-face meetings Group meetings
	United States	n <sub>E</sub> = 26; 26 (13 SCI)			

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		$n_c = 18; 18$			
Foulon (2013)	RCT		To explore the effectiveness of informational portrait vignettes for enhancing physical activity-related psychosocial cognitions in persons with SCI who were classified as being in the motivational (E1, C1) or volitional (E2, C2) phase of behavior change	Home-based	E-mail
Canada		$n_{E1} = 18; 18$ $n_{E2} = 24; 24$ $n_{c1} = 14; 14$ $n_{c2} = 23; 23$			
Froehlich-Grobe (2004)	RCT		To assess the effectiveness of a physical activity and fitness intervention for women with a physical disability	Self-selected by participants	Telephone Face-to-face meetings
United States		$n_E = 42; 32$ (6 SCI) $n_c = 51; 43$ (5 SCI)			
Froehlich-Grobe (2012, 2014)	RCT		To compare the effectiveness of staff-supported (E) versus self-guided (C) home-based behavioral interventions promoting exercise adoption and maintenance for wheelchair users	Home-based	Telephone Face-to-face meetings Mail
United States		$n_E = 69; 51$ (35 SCI) $n_c = 59; 35$ (24 SCI)			
Kosma (2005)	RCT		To assess the efficacy of a web-based LTPA motivational program tailored to inactive adults with physical disabilities	Home-based	Web
United States		$n_E = 101; 46$ (12 SCI) $n_c = 50; 29$ (13 SCI)			
Latimer (2006)	RCT		To evaluate the efficacy of an implementation intentions intervention for promoting physical activity among persons with SCI	Home-based	Telephone E-mail
Canada		$n_E = 26; 19$ $n_c = 28; 18$			
Nooijen (2016, 2017)	RCT		To assess, for people with subacute SCI, if rehabilitation that is reinforced with the addition of a behavioral intervention to promote physical activity leads to (1) a better health, participation, and quality of life and (2) a more active lifestyle than rehabilitation alone	Rehabilitation centre	Face-to-face meetings Telephone
Netherlands		$n_E = 20; 11$ $n_c = 19; 11$			

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Rimmer (2013)	RCT	To examine the effects of a low-cost, telephone-based weight management program using a web-based system (Personalized Online Weight and Exercise Response System [POWERS]) for overweight and obese adults with a physical disability, within three conditions: physical activity only (E1), physical activity plus nutrition (E2) and control (C)	Home-based	E-mail
United States	n <sub>E1</sub> = 32; 32 (7 SCI) n <sub>E2</sub> = 32; 27 (8 SCI) n <sub>c</sub> = 38; 32 (9 SCI)			
van der Ploeg (2007)	Quasi-experimental	To determine the effects of the physical activity promotion programs Rehabilitation & Sports (E1) and Rehabilitation and Sports paired with Active after Rehabilitation (E2) on sport and daily physical activity 1-year after in- or outpatient rehabilitation	Medical centre- and home-based	Telephone Face-to-face meetings
Netherlands	n <sub>E1</sub> = 315; 224 n <sub>E2</sub> = 284; 208 n <sub>c</sub> = 603; 533			
Wickham (2000)	Quasi-experimental	To determine whether introduction to adapted sports in a wheelchair sports camp causes a measurable change in attitudes and motivation toward leisure physical activity	Camp-based	Face-to-face meetings Group meetings
United States	n <sub>E</sub> = 12; 12 n <sub>c</sub> = 12; 12			
Wise (2009), Thomas (2011)	RCT	To examine changes in physical activity in persons with SCI through regular participation in a tailored home exercise program	Home-based	Telephone Face-to-face meetings Printed materials DVD/video
United States	n <sub>E</sub> = NS; 10 n <sub>c</sub> = NS; 11			
Zahl (2008)	Quasi-experimental	To determine the effectiveness a self-efficacy and self-affirmation based educational forum on active living among adults with SCI and spinal cord disease	Unspecified	Face-to-face meetings Group meetings
United States	n <sub>E</sub> = 13; 13 n <sub>c</sub> = 14; 14			
Zemper (2003)	RCT	To determine the effect of a comprehensive and integrated holistic wellness program among persons with SCI	Hospital-based	Telephone Face-to-face meetings
United States	n <sub>E</sub> = 36; 23 n <sub>c</sub> = 31; 20			

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*Note.* Sample size: E = experimental condition; C = comparison condition; E1 = first experimental condition; E2 = second experimental condition; C1 = first comparison condition; C2 = second comparison condition. Study Design: RCT = randomized controlled trial. Purpose: SCI = spinal cord injury; LTPA = leisure time physical activity.

Table S3

Cochrane Risk of Bias Table for Included Randomized Controlled Trials (n = 12).

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Arbour-Nicitopoulos (2009)							
Arbour-Nicitopoulos (2017)							
Bassett-Gunter (2013)				N/A			
Foulon (2013)				N/A			
Froelich-Grobe (2004)							
Froelich-Grobe (2012, 2014)							
Kosma (2005)							
Latimer (2006)							
Nooijen (2016, 2017)							
Rimmer (2013)							
Wise (2009), Thomas (2011)							
Zemper (2003)							

*Notes.* + = low risk of bias (i.e., plausible bias unlikely to seriously alter the results); ? = unclear risk of bias (i.e., plausible bias that raises some doubt about the results); - = high risk of bias (i.e., plausible bias that seriously weakens confidence in the results); N/A = outcomes assessments occurred via electronic mail or web, consequently no personnel was involved which eliminated avoiding risk of detection bias. The Cochrane Risk Of Bias Assessment Tool was used to determine risk of bias (Higgins et al., 2011).

Table S4

*Risk of Bias Results for Included Non-Randomized Studies (n = 19).*

Study	Overall Risk of Bias	Confounding	Selection of Participants	Measurement of Interventions	Departures from Intended Interventions	Missing Data	Measurement of Outcomes	Selection of Reported Result
Arbour-Nicitopoulos (2014)	Moderate	Moderate	Low	Low	Low	Low	Moderate	Low
Bassett (2011)	Serious	Serious	Moderate	Low	Low	Moderate	Serious	NI
Block (2010)	Serious	Moderate	Serious	Low	Low	Low	Serious	NI
Brawley (2013)	Serious	Moderate	Serious	Low	Low	NI	Serious	Low
de Oliveira (2016)	Serious	Serious	Serious	Low	Low	NI	Serious	NI
Gainforth (2013)	Serious	Serious	Serious	Low	Low	Moderate	Serious	NI
Lai (2016)	Serious	Serious	NI	Low	Low	NI	Serious	NI
Latimer-Cheung (2013)	Serious	Moderate	Serious	Low	Low	NI	Serious	NI
Latimer-Cheung (2013)	Serious	Moderate	Serious	Low	Low	NI	Serious	NI
Myers (2012)	Serious	Serious	Serious	Low	NI	NI	Moderate	NI
Pelletier (2014)	Serious	Serious	Low	Low	Low	NI	Serious	NI
Piatt (2012)	Serious	Serious	Serious	Low	Low	NI	Serious	Serious
Radomski (2011)	Serious	Moderate	Serious	Low	Moderate	NI	Low	Serious
Sheehy (2013)	Serious	Serious	Serious	Low	Low	NI	Moderate	NI
Tomasone (2016)	Serious	Low	High	Low	Low	High	High	NI
Van der Ploeg (2007)	Serious	Serious	Moderate	Serious	Moderate	NI	Serious	Low
Warms (2004)	Serious	Serious	Moderate	Low	Low	NI	Moderate	NI
Wickham (2000)	Serious	Serious	Serious	Low	Low	NI	Serious	NI
Zahl (2008)	Serious	Serious	Serious	Low	Serious	NI	Serious	NI

*Note.* NI = No information. A Cochrane Risk Of Bias Assessment Tool for Non-Randomized Studies of Interventions (ACROBAT-NRSI) was used to determine risk of bias (Sterne et al., 2014).

## Item S5

*References for Leisure-Time Physical Activity Measures Referred to in Table 2.*

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