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Physical activity and subjective well-being among people with spinal cord injury: a meta-analysis

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Study design: Meta-analysis of cross-sectional, quasi-experimental and experimental studies.
Objective: To determine if there is an association between physical activity (PA) and subjective well-being (SWB) among people living with spinal cord injury (SCI).
Methods: Literature searches were conducted using multiple databases (Embase, CINAHL, Medline, PsychINFO and SPORTDiscus) to identify studies involving people with SCI that included a measure of PA and at least one measure of SWB (for example, symptoms of depression, life satisfaction, mood). Relevant data were extracted from the studies and subjected to meta-analysis.
Results: A total of 21 studies were retrieved yielding 78 effect sizes and a total sample size of 2354. Overall, there were statistically significant, small- to medium-sized effects for the relationships between PA and SWB (broadly defined), PA and depressive symptoms, and PA and life satisfaction. Studies using experimental and quasi-experimental designs yielded larger effects for SWB (broadly defined) and life satisfaction, than studies using nonexperimental study designs.
Conclusions: There is a small- to medium-sized positive relationship between PA and SWB among people with SCI that holds across a wide range of measures and operational definitions of these constructs.
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Keywords: life satisfaction; depression; exercise; sport; satisfaction

Introduction

Subjective well-being (SWB) refers to a broad category of phenomena that encompasses life satisfaction, satisfaction with important life domains, and positive and negative affect.[1] Examples of SWB dimensions include satisfaction with life, health and physical functioning, depression and anxiety.

On average, people living with spinal cord injury (SCI) tend to report poorer SWB than those without disabilities.[2] In an attempt to better understand and ultimately improve SWB in the SCI population, researchers have examined a wide range of potential correlates and predictors of SWB. In meta-analytic and narrative reviews, various factors have been shown to positively correlate with SWB, including social integration, employment, community access and social support.[2–4] However, one factor that has received very little attention in these reviews is physical activity (PA).

Among the general population and several clinical populations, a considerable amount of research has shown that regular participation in PA is associated with improvements in a wide range of SWB outcomes.[5] For example, meta-analyses have documented the effectiveness of PA for decreasing depressive symptoms,[6] improving mood[7] and enhancing various dimensions of life satisfaction.[8] In contrast, relatively little research has examined PA and SWB among people living with SCI. Furthermore, of the few SCI studies that have been conducted, some have shown large, statistically significant positive associations between PA and SWB, for example Hicks *et al.*[9] and Ditor *et al.*,[10] whereas others have shown much smaller and even non-significant associations, for example Foreman *et al.*[11] and Tasiemski *et al.*[12]

These inconsistent findings likely reflect key methodological differences across studies. For instance, the conceptual definitions and measures of SWB have varied from one study to the next. Also, different investigators have used different definitions of PA (for example, playing sports, participating in a sports camp, belonging to an exercise program). And finally, researchers who have implemented PA interventions to improve SWB have prescribed different activity types, intensities and durations, for example Hicks *et al.*[9] and Kennedy *et al.*[13] With so many different conceptualizations of key constructs, it is not surprising that studies have yielded inconsistent results.

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Another factor that might account for inconsistent findings is a lack of statistical power. Many of the published studies involving people with SCI were underpowered to detect the small- to medium-sized relationships between PA and SWB that are typically seen in the general population.[5,14] The minimum sample sizes required to detect statistically significant ($P<0.05$) small-sized ($r=0.10$) and medium-sized ($r=0.30$) relationships are 783 and 85 participants, respectively.[15] Thus, it is not clear if the statistically nonsignificant effects reported in some studies were due to underpowered study designs.

Given the above-cited limitations, it is very difficult to generate meaningful conclusions regarding the nature of the relationship between PA and SWB in people with SCI. Meta-analysis is a viable method for addressing these limitations. Specifically, meta-analysis is a data synthesis technique whereby individual study findings are expressed as a common metric and subsequently pooled to examine research hypotheses. Factors that may moderate the relationships observed in individual studies, such as study design characteristics, can be addressed in a meta-analysis of the pooled studies. A moderator analysis is conducted by calculating and comparing the average effect sizes (ESs) across studies with different characteristics. Study design is an important consideration in the SCI PA literature, which is largely comprised of nonexperimental studies.[16] It is important to know if a reliance on nonexperimental designs is potentially hindering our understanding of the PA–SWB relationship.

The primary purpose of our meta-analysis was to examine the relationship between PA and SWB among people with SCI. To address this objective, SWB was broadly defined to encompass the many operational definitions of SWB used in the SCI literature. A secondary purpose was to examine the relationship between PA and the specific SWB constructs (for example, life satisfaction) that have been most studied in the SCI and PA literature. Consistent with research in the general and clinical populations, for example references,[6–8,14] it was hypothesized that PA and SWB would be positively related. A third purpose was to examine study design as a moderator of the PA–SWB relationship to determine if it can account for inconsistencies in the existing literature.[17]

Materials and methods

Identification and inclusion of studies

A comprehensive search of computer databases (Embase, CINAHL, Medline, PsychINFO and SPORTDiscus) was conducted to identify relevant English-language studies of PA and SWB in people with SCI that were published before February 2008. Manual searches were conducted from the reference lists in review articles and in relevant studies that were identified through the computer search.

In the exercise science literature, PA is broadly defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure'.[18] This definition encompasses all types of activity (for example, occupational activity, activities of daily living, sports, exercise). However, for the purpose of our meta-analysis and consistent with other meta-analyses conducted in the PA domain,[6] we focused on studies that examined participation in sport (both competitive and noncompetitive) and other activities that are carried out to improve or maintain one or more components of physical fitness (that is, aerobic fitness, muscular strength and endurance, body composition and flexibility).

Subjective well-being was defined according to Diener's conceptualization of the construct (that is, pleasant affect, unpleasant affect, life satisfaction and domain satisfactions).[1] We searched for studies that included measures of life satisfaction, satisfaction with important life domains (for example, health, leisure, self), positive affect and negative affect. In all, 12 PA and 21 SWB search terms were used in our literature searches. A complete list of search terms is presented in Appendix A.

A total of 21 studies met the following inclusion criteria: (1) the majority of study participants (that is, $\geqslant 51\%$) had an SCI; (2) PA was measured directly by self-report or observation, or indirectly (for example, physical fitness), or the investigators used a method for categorizing participants as physically active/inactive; (3) study included at least one measure of SWB and (4) adequate data were provided to calculate an ES. Seven authors of studies with incomplete or missing information were contacted and five responded with requested information. The remaining two studies were excluded from the meta-analysis.

Data extraction and coding

Information was extracted from the studies regarding sample characteristics (sample type and size), study design, operational definitions of PA and SWB, and raw data for the calculation of ESs. All data were independently extracted and coded by the first author and either the second or fourth author. Discrepancies were discussed and resolved through consensus.

Computation of effect sizes

The measure of ES was *r*. For studies that reported data with statistics other than *r* (for example, means and standard deviations, χ^2-test), the data were extracted and converted to *r*s using formulas described by Hunter and Schmidt.[19] For ease of interpretation, ESs were coded as positive if PA was associated with better SWB (for example, less depression, greater life satisfaction), and negative if PA was associated with poorer well-being (for example, greater depression, poorer life satisfaction). For studies with more than one ES, an average ES was computed across all of that study's ESs, to maintain statistical independence of effects.

Meta-analyses

An initial meta-analysis was conducted on all of the SWB measures (that is, SWB broadly defined). Separate meta-analyses were then conducted for the specific SWB constructs that have been most studied in the SCI and PA literature (that is, the specific SWB constructs that yielded the most ESs in our literature search). The meta-analyses used a bare-bones analysis,[19] which corrects for sampling error due to variation in sample size across studies by computing a weighted average in which each correlation is weighted by the number of persons in that study. Sampling error is the difference between the characteristics of a sample and those of the population from which it is drawn. The ES is a combination of the true size of the relationship in a population plus error (or unknown variance attributed to unmeasured variables that could influence the relationship).[19] Typically, larger sampling error occurs in smaller-sized samples. Given the characteristically small samples used in studies of PA among people with SCI,[16] it was considered important that our meta-analyses control for sampling error.

A random effects meta-analysis was used. A random effects model allows for the possibility that the true ES size varies from one study to the next, depending on study characteristics (for example, participants, intervention length, study quality).[19] If it were possible to conduct an infinite number of studies, the true ESs would be distributed around a mean. The studies included in the meta-analysis are presumed to represent a random sample of these ESs (hence the term 'random effects').[20] Given that we included studies that used different designs and measures of PA and SWB, a random effects model was considered appropriate.

For each meta-analysis, the following statistics were calculated: total sample size (N), number of ESs (K), sample-size weighted mean observed correlation (r_{obs}), sample-size weighted standard deviation of observed correlations (s.d.$_{obs}$), 95% confidence interval (95% CI), percent of r_{obs} variance due to sampling error (%Var$_e$), 95% credibility interval (95% CrI) and fail-safe N (r_{fs}). The mean observed correlation was interpreted according to Cohen's guidelines, whereby *r*s of 0.10, 0.30 and 0.50 represent small, medium and large effects, respectively.[15] The CI was calculated to allow for interpretation of the meaningfulness of the ES beyond its magnitude. CIs that do not capture zero are indicative of statistically significant effects. The credibility interval was calculated to provide an estimate of the true range of ESs that may exist within the population of ESs. Generalizability is indicated when the upper and lower bounds of the CrI do not cross zero.[21] Note that whereas the CI provides information about estimates of a single value, the credibility index provides information on the distribution of parameter values. Fail-safe N was calculated as a measure of study availability bias (or publication bias). This value represents the number of studies with nonsignificant results that would be needed to reduce the overall ES to the lowest critical ES considered practically or theoretically meaningful.[19] The critical ES was set at $r = 0.20$, indicative of a small- to medium-sized effect.[15]

Results

Description of the data

The 21 studies meeting the inclusion criteria (Table 1) yielded a total of 78 ESs and a total N of 2354. Regarding *sample* characteristics, 16 studies included both paraplegic and tetraplegic participants, 2 included paraplegics only and 3 included paraplegic, tetraplegic participants and people with disabilities other than SCI. Sample sizes ranged from $n = 7$ to $n = 985$ ($M = 112$, median $= 41$). Regarding *study* characteristics, 12 studies used a cross-sectional study design, 6 a pre-post single-group design, 2 a nonrandomized experimental design and 1 a randomized controlled design.

Physical activity was operationally defined in a variety of ways: participation in a program or intervention (nine studies), being an athlete (four studies), activity frequency (six studies) and self-reported energy expenditure during leisure activities (one study). One study used two measures: endurance capacity and energy expenditure. Fourteen different SWB constructs were assessed (Table 2). Depressive symptoms and life satisfaction were the SWB constructs most frequently assessed (in 15 and 8 studies, respectively) and were thus submitted to separate meta-analyses. All other SWB constructs were measured in $\leqslant 5$ studies. Given the relatively small number of ESs available for these other constructs, they were not submitted to separate meta-analyses.

Meta-analyses

There was a statistically significant, small- to medium-sized, positive relationship between PA and SWB broadly defined ($r_{obs} = 0.25$; 95% CI 0.19–0.31). The forest plot for this meta-analysis is shown in Figure 1. The fail-safe N indicates that five studies with nonsignificant effects would be needed to reduce r_{obs} to <0.20 (that is, the smallest ES considered meaningful). Interpretation of the 95% CrI suggests that the results generalize across studies.

Statistically significant small- to medium-sized effects also emerged for life satisfaction and depressive symptoms. PA was associated with greater life satisfaction ($r_{obs} = 0.23$; 95% CI 0.16–0.30) and lower scores on indices of depression ($r_{obs} = 0.22$; 95% CI 0.16–0.28). Forest plots for the meta-analyses of life satisfaction and depression are shown in Figures 2 and 3, respectively. The calculated fail-safe *N*s of 1 and 2 were not suggestive of a strong tolerance to availability bias. The CrI values were indicative of generalizable relationships.

Moderator analysis: study design. When planning our meta-analysis, we intended to compare ESs across three types of study designs: cross-sectional, quasi-experimental and experimental. However, our literature search yielded a majority of cross-sectional studies. With so few ESs from experimental and quasi-experimental studies, our original analysis plan could not proceed. Consequently, a decision was made to group together the studies using experimental designs with the studies using quasi-experimental designs to create an 'experimental or quasi-experimental' design category. ESs for these studies were then compared with the cross-sectional studies, which were categorized as 'nonexperimental'.

As shown in Table 3, experimental and quasi-experimental studies demonstrated somewhat stronger patterns of association between PA and SWB than nonexperimental studies. Specifically, the nonexperimental studies yielded small- to medium-sized effects ($r_{obs} = 0.24$; 95% CI 0.17–0.31) whereas

Table 1 Characteristics of studies included in the meta-analysis

Study	*Sample*	N	*Design*	*Definition of activity*	*Subjective well-being constructs included in the meta-analysis (number of ESs shown in parentheses)*
Bradley	P	37	Nonrandomized experimental	Participation in FES cycling intervention	Depression (1), hostility (1)
Ditor *et al.*	P and T	7	Pre-post single group	Frequency of exercise	Life satisfaction (1), depression (1), satisfaction with function (1) and appearance (1), stress (1)
Eng *et al.*	P and T	38	Cross-sectional	Frequency of standing	Fatigue (1), well-being (1)
Foreman *et al.*	P and T	121	Cross-sectional	Athlete/Non-athlete	Depression (1)
Gioia *et al.*	P and T	137	Cross-sectional	Activity frequency	Depression (1)
Greenwood *et al.*	P, T, O	127	Cross-sectional	Athlete/Non-athlete	Confusion (1), tension (1), vigor (1), fatigue (1), anger (1), depression (1)
Guest *et al.*	P	15	Pre-post single group	Participation in FES walking intervention	Self-concept (1), depression (1)
Hicks *et al.*	P and T	34	Randomized controlled trial	Participation in aerobic and strength training intervention	Satisfaction with physical function (1) and appearance (1), stress (1), perceived health (1), depression (1), life satisfaction (1)
Hicks *et al.*	P and T	14	Pre-post single group	Participation in treadmill training intervention	Depression (1), life satisfaction (1), satisfaction with physical function (1), perceived health (1)
Jacobs *et al.*	P, T, O	150	Cross-sectional	Athlete/Non-athlete	Tension (1), vigor (1), confusion (1), fatigue (1), anger (1), depression (1)
Kennedy *et al.*	P and T	35	Pre-post single group	Participation in an activity course	Life satisfaction (1), depression (1)
Loy and Dattilo	P and T	178	Cross-sectional	Activity intensity	Depression (1), perceived health (1), well-being (1)
Manns and Chad	P and T	38	Cross-sectional	Fitness, energy expenditure	Life satisfaction (4)
Muraki *et al.*	P and T	169	Cross-sectional	Active/Non-active	Depression (4), state anxiety (2), tension (2), vigor (2), confusion (2), fatigue (2), anger (2)
Nawoczenski *et al.*	P and T	41	Nonrandomized experimental	Participation in stretch and resistance training intervention	Satisfaction with physical (shoulder) function (1)
Paulsen *et al.*	P, T, O	54	Cross-sectional	Athlete/Non-athlete	Tension (1), vigor (1), confusion (1), fatigue (1), anger (1), depression (1)
Semerjian *et al.*	P and T	12	Pre-post single group	Participation in resistance training, ergometery, standing and walking intervention	Life satisfaction (1), satisfaction with physical function (1) and appearance (1)
Sipski *et al.*	P and T	47	Cross-sectional	Participation in FES biking intervention	Self-concept (2), satisfaction with appearance (2)
Tasiemski *et al.*	P and T	985	Cross-sectional	Frequency of sports participation	Life satisfaction (1), depression (1)
Walter *et al.*	P and T	99	Cross-sectional	Frequency of standing	Life satisfaction (1)
Warms *et al.*	P	16	Pre-post single group	Participation in activity counseling intervention	Perceived health (1), depression (1)

Abbreviations: ESs, effect sizes; FES, functional electrical stimulation; P, paraplegic; T, tetraplegic; O, people with other types of disabilities.

the experimental and quasi-experimental studies yielded medium–large effects ($r_{obs}=0.38$; 95% CI 0.30–0.46), with minimal overlap in CIs for the two types of studies. Interpretation of the 95% CI and 95% CrI indicates statistically significant and generalizable effects for both study types. The fail-safe *N* was markedly larger for the experimental and quasi-experimental studies ($r_{fs}=8$) than the nonexperimental studies ($r_{fs}=2$).

For life satisfaction, a small- to medium-sized effect emerged from the nonexperimental studies ($r_{obs}=0.21$; 95% CI 0.04–0.29), whereas the effect for the experimental and quasi-experimental studies bordered on large ($r_{obs}=0.45$; 95% CI 0.31–0.59). There was no overlap in the CIs for the two types of studies. Both effects were statistically significant and generalizable. The fail-safe *N* was larger for experimental and quasi-experimental ($r_{fs}=6$) than nonexperimental studies ($r_{fs}=1$).

For the meta-analysis of depressive symptoms, there was little difference between the effects observed for experimental and quasi-experimental studies ($r_{obs}=0.27$; 95% CI 0.14–0.41) compared to nonexperimental studies ($r_{obs}=0.22$; 95% CI 0.14–0.29). Both effects were small to medium sized and there was overlap of the CIs. Although both effects were statistically significant and generalizable, the very small fail-safe *N*s ($r_{fs}\leqslant 2$) indicate poor tolerance to study availability bias.

Table 2 Subjective well-being constructs measured in studies included in the meta-analysis

Construct	*No. of studies*	*No. of ESs*
Confusion	4	4
Depressive symptoms	15	18
Fatigue	5	6
Hostility/Anger	5	6
Perceived health	4	4
Life satisfaction	8	11
Satisfaction with physical appearance	4	5
Satisfaction with physical function	5	5
Self-concept	2	3
State anxiety	1	2
Stress	2	2
Tension	4	5
Vigor	4	5
Well-being	2	2

Abbreviation: ESs, effect sizes.

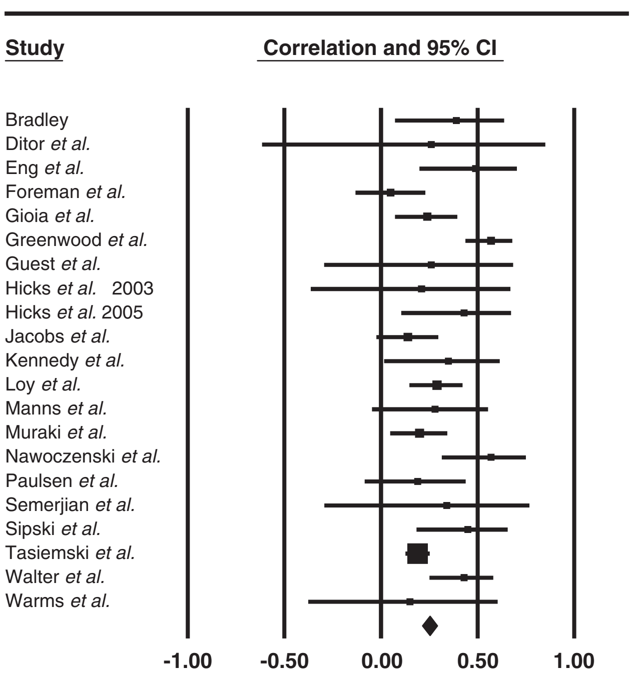

Figure 1 Forest plot for the meta-analysis of studies examining the relationship between physical activity and subjective well-being (broadly defined). Larger squares indicate larger study sample sizes. The diamond indicates the overall ES for the meta-analysis.

All of the above meta-analyses were subsequently recomputed without the three studies that included participants with disabilities other than SCI. There was virtually no difference between the results presented above and the results with these three studies removed.

Discussion

The purpose of this meta-analysis was to examine the relationship between PA and SWB among people living with SCI. Similar to findings reported in general and clinical populations,[5,8,14] statistically significant small- to medium-sized effects emerged when SWB was defined both broadly (that is, the meta-analysis including all measures of SWB) and more specifically (that is, the two separate meta-analyses of measures of depressive symptoms and life satisfaction). Furthermore, the relationships held despite the inclusion of a broad range of measures used in the studies included in our meta-analysis. Taken together, these findings attest to the robustness of the PA–SWB association among people with SCI.

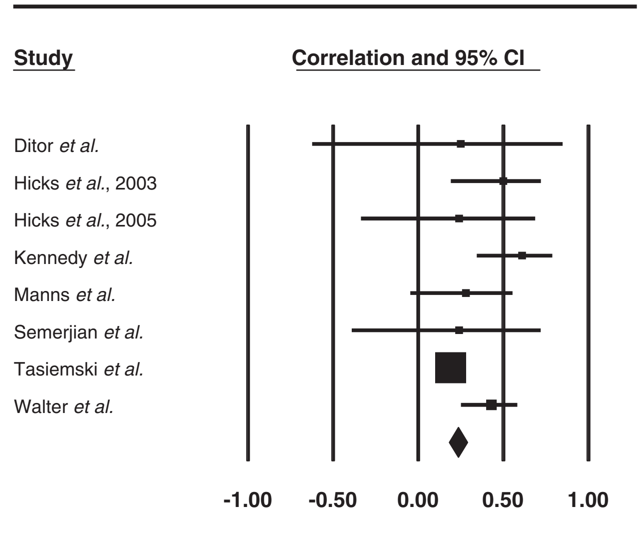

Figure 2 Forest plot for the meta-analysis of studies examining the relationship between physical activity and life satisfaction. Larger squares indicate larger study sample sizes. The diamond indicates the overall effect size (ES) for the meta-analysis.

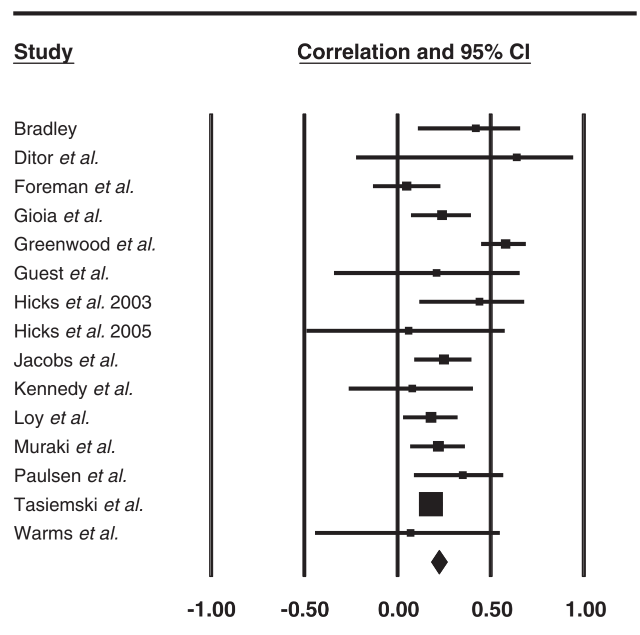

Figure 3 Forest plot for the meta-analysis of studies examining the relationship between physical activity and symptoms of depression. Larger squares indicate larger study sample sizes. The diamond indicates the overall effect size (ES) for the meta-analysis.

Table 3 Meta-analysis of the relationship between physical activity and subjective well-being

Analysis	N	K	r_{obs}	$s.d._{obs}$	*95% CI*	$\%Var_e$	*95% CrI*	r_{fs}
Overall analysis: subjective well-being broadly defined								
Subjective well-being	2354	21	0.25	0.13	0.19–0.31	0.008	0.23–0.27	5
Specific dimensions of subjective well-being								
Life satisfaction	1224	8	0.23	0.10	0.16–0.30	0.006	0.22–0.24	1
Depressive symptoms	2079	15	0.22	0.12	0.16–0.28	0.007	0.21–0.24	2
Moderator: study design								
SWB: nonexperimental	2143	12	0.24	0.11	0.17–0.31	0.006	0.22–0.26	2
SWB: quasi and experimental	211	9	0.38	0.12	0.30–0.46	0.033	0.34–0.41	8
LS: nonexperimental	1122	3	0.21	0.07	0.14–0.29	0.002	0.21–0.22	1
LS: quasi and experimental	102	5	0.45	0.16	0.31–0.59	0.034	0.45–0.45	6
DEP: nonexperimental	1921	8	0.22	0.11	0.14–0.29	0.004	0.20–0.23	1
DEP: quasi and experimental	158	7	0.27	0.18	0.14–0.41	0.041	0.26–0.28	2

Abbreviations: SWB, subjective well-being; LS, life satisfaction; DEP, symptoms of depression; *N*, total sample size; *K*, number of ESs; r_{obs}, sample size weighted mean observed correlation; 95% CI, r_{obs} 95% confidence interval; $s.d._{obs}$, sample size weighted s.d. of observed correlations; $\%Var_e$, percent of r_{obs} variance due to sampling error; 95% CrI, 95% credibility interval; r_{fs}, r_{obs} fail-safe *N* with *ES* = 0.20; $r_{unlocated}$ = 0.00 for r_{obs} values above 0.20.

For the analyses of SWB broadly defined and life satisfaction, the effects were stronger in studies that used experimental/quasi-experimental designs than in studies using nonexperimental designs. One possible explanation for these findings is that better, more reliable measures of SWB were used in the experimental/quasi-experimental studies. Because so few studies provided measurement reliability data, this possibility is difficult to confirm. We also suspect that there was better measurement and control over the types and amounts of PA performed in the experimental/quasi-experimental studies, than in the nonexperimental studies. As characteristics of PA—such as activity type, frequency, duration and intensity—can influence the PA–SWB relationship,[5,14] it is understandable that studies with at least some control over, and measurement of, these variables would yield greater effects.

For the analyses of symptoms of depression, there was essentially no difference in the ESs for experimental/quasi-experimental studies compared to nonexperimental studies. Both types of studies yielded similarly small- to medium-sized effects. This finding was somewhat surprising given that a meta-analysis of randomized controlled trials (RCTs) provided evidence of very large effects (ES = 1.10) of exercise interventions on depressive symptoms.[6] However, there was only one study[9] in our meta-analysis that used an RCT design to examine the effects of exercise on depressive symptomatology. Furthermore, there were only eight studies in the meta-analysis of nonexperimental studies of depression symptoms, and most of these failed to account for factors known to influence the effects of PA on clinical depression (for example, PA program duration, frequency and intensity[5]). Thus, the ESs reported in Table 3 may underestimate the true effects of PA on depression symptoms in well-controlled intervention studies that are designed to maximize PA's efficacy as a treatment for depressive symptoms.

Considering that virtually all of the experimental/quasi-experimental studies implemented some type of PA intervention (for example, circuit training, sports course, functional electrical stimulation (FES) cycling), the medium- to large-sized effects for these studies may indicate the effectiveness of PA as a treatment modality for improving SWB (broadly defined) and life satisfaction. However, given that only one study used a randomized controlled design,[9] it would be premature to conclude from these data that PA causes improvements in SWB. Alternatively, it is possible that people who choose to exercise (as in the nonrandomized studies) already experience better SWB. It is also possible that a third variable could account for the PA–SWB association. For instance, people with better physical functioning might experience greater SWB and be more physically active than those with poorer physical functioning. One important step toward establishing a causal relationship between PA and SWB is to conduct more high-quality, experimental studies that demonstrate the effects of PA interventions on SWB in people with SCI.

Another important step toward establishing causality is to demonstrate the plausibility of a causal relationship between PA and SWB.[22] This is accomplished by explaining the relationship in terms of its underlying mechanisms. Several plausible mechanisms have been hypothesized to account for the positive relationship between PA and SWB.[5,14] For example, PA may impart feelings of accomplishment and mastery, which can subsequently enhance feelings of self-worth, self-efficacy and personal control. PA may also provide opportunities for social interaction, thus fostering community integration and improving life satisfaction. In addition, there is evidence that exercise can increase the production rate of neurotransmitters that help to regulate emotion and prevent or alleviate depression (for example, serotonin, norepinephrine, dopamine).[23,24] To date, only one published study has examined the mechanisms underlying the PA–SWB relationship in people with SCI.[25] In that study, Martin Ginis *et al*. identified pain reduction as a mechanism by which exercise improves life satisfaction and depressive symptoms. Additional research is needed to determine other mechanisms by which PA may improve SWB in people with SCI.

One limitation of this meta-analysis is that there were insufficient studies to analyze moderators other than study design. For instance, it would have been ideal to examine PA characteristics (that is, activity type, intensity, duration, frequency) as potential moderators. Another limitation is that we were unable to correct the ESs for reliability bias because only 4 of the 21 studies provided measurement reliability data. (Parenthetically, many of the study authors reported on the reliability of their measures when used in other studies, but not in their own studies.) The PA–SWB relationship may be attenuated if SWB is assessed using unreliable measures.[19] Given the questionable psychometric quality of SWB measures typically used in SCI research,[3,26] it is possible that the ESs in Table 3 underestimate the strength of the relationships between PA and SWB.

In addition to estimating the strength of the PA–SWB relationship, our meta-analysis has provided an opportunity to catalog and review the existing literature. Several recommendations can be made based on this review. First, although a variety of SWB constructs have been examined, most research has focused on life satisfaction and depressive symptoms. Given that SWB encompasses a wide range of human experiences,[1,27] investigators should expand their conceptualizations of SWB beyond life satisfaction and symptoms of depression to examine other dimensions, such as those listed in Table 2. Although we are not necessarily suggesting that researchers include a large number of SWB outcome measures in their studies, we do encourage the investigation of affective dimensions other than depression and further examination of subdomains of life satisfaction. Our second recommendation is based on the observation that only three studies had a control group. As a step toward establishing the causal effects of PA on SWB, investigators must use experimental research designs. Third, we encourage study authors to report on the psychometric properties of measures used in their studies and to provide detailed information on PA interventions so that these characteristics can be considered in future meta-analyses. Finally, we urge researchers to use measures of PA that have been validated for use within the SCI population and that assess the multiple dimensions of PA (that is, type, frequency, intensity and duration).[28] Studies that include more detailed measures of PA will allow researchers to better identify the types and amounts of activity most conducive to SWB.

In summary, our meta-analysis has clearly established a statistically significant, positive relationship between PA and SWB. Although additional well-controlled, experimental studies are needed to establish whether this is a causal relationship, the strength and direction of the relationship are encouraging. Confirmation of the positive effects of PA on SWB would provide yet another impetus for the development of interventions to increase PA in this very inactive population.[29] Not only do physically active people with SCI enjoy better health and reduced risk for chronic disease,[30] but they may also enjoy better SWB.

Acknowledgements

We thank two anonymous reviewers who provided comprehensive feedback on previous versions this paper. Feedback from Reviewer A resulted in a substantial narrowing of the scope of our meta-analysis and the subsequent exclusion of several studies that were not aligned with the reviewer's definition of subjective well-being. Although removal of these studies had minimal effect on the overall r_{obs}, exclusion of these studies did improve the symmetry of the data and narrowed the confidence intervals. Investigators who use alternative conceptualizations of subjective well-being in future meta-analytic reviews may yield somewhat different results from those reported herein. This study was sponsored by a Canadian Institutes of Health Research New Investigator Award awarded to KA Martin Ginis.

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Appendix A

Physical activity search terms: physical activity, sport, exercise, fitness, training, exercise adherence, leisure, functional electrical stimulation (FES), body-weight supported treadmill training (BWSTT), standing, ambulation, endurance capacity.

Subjective well-being search terms: subjective well-being, quality of life (QOL), life satisfaction, satisfaction, stress, physical self-concept, depression, anxiety, vigor, mood, perceived health, affect, well-being, confusion, fatigue, hostility, anger, health-related quality of life (HRQOL), body image, self-concept, tension.

Appendix B

Studies included in the meta-analysis that are not referenced above

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