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Improved quality of life and body satisfaction in response to activity-based therapy in adults with spinal cord injury

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Abstract

Aim: The decline in ambulation characteristic of spinal cord injury (SCI) dramatically modifies quality of life and body composition. To examine changes in quality of life, body satisfaction, and body composition in response to 6 months of activity-based therapy in individuals with spinal cord injury (SCI).

Methods: Men and women with complete or incomplete SCI (12 with tetraplegia and 13 with paraplegia; mean age and duration of injury of 35.8 ± 12.9 years and 3.8 ± 5.5 years, respectively) completed 6 months of activity-based therapy consisting of load bearing, locomotor training, whole-body resistance training, functional electrical stimulation, and assisted/unassisted walking for 8.5 ± 4.3 h/week. At baseline and at 3 and 6 months of training, body satisfaction, perceived quality of life, depression, and bodily pain were assessed using various questionnaires, and whole-body and regional fat mass and fat-free mass were determined with dual-energy X-ray absorptiometry. One-way analysis of variance with repeated measures was used to examine changes in outcome measures during the study.

Results: Measures of body satisfaction (+23%) and quality of life (+8%) were improved ($P < 0.05$) in response to training, yet no change in depression or pain was demonstrated ($P > 0.05$). Percent body fat increased ($P = 0.02$), yet no change ($P > 0.05$) was seen in whole-body or regional fat free mass.

Conclusion: Data suggest that chronic high-volume activity-based therapy enhances various indices of quality of life in men and women with SCI, but may be an ineffective approach to reduce fat deposition and increase muscle mass after SCI.

Keywords: Body satisfaction, depression, rehabilitation, fat free mass, paralysis

INTRODUCTION

The paralysis associated with spinal cord injury (SCI) compromises locomotion and, in turn, diminishes physical function and leads to various secondary complications including obesity and insulin resistance[1]. Above and beyond the physical effects of SCI is the onset of various psychological issues that may affect perceived quality of life (PQOL), which encompasses aspects of happiness, health, quality of family relationships, and financial and physical independence[2]. In fact, in men and women with SCI, well-being is negatively associated with self-reported overweight status and onset of secondary complications[3], which emphasizes the need to also consider participants' psychological state during rehabilitation. Data on persons with SCI demonstrate that aerobic and resistance exercise training improves PQOL compared to non-exercising controls[4], although PQOL was reduced after a decline in physical activity three months later[5]. Incidence of pain is also common in SCI, as, in a survey of 200 individuals, 25% had more severe pain and 44% reported that it interfered with daily activities[6]. Moreover, pain decreases quality of life and serves as a barrier to regular exercise participation in SCI[6]. In addition, more pain is consequent with greater incidence of depression[7], which is widely studied in persons with SCI[8], and incidence of substantial pain may negatively influence participation in rehabilitation. Moreover, depression is associated with body image disturbances and body dissatisfaction, which are common in persons with disability such as SCI[9]. With exception of one study showing positive effects on quality of life[4], little is known about efficacy of exercise training to modify quality of life and body satisfaction in SCI.

As stated above, quality of life is associated with body composition that is severely altered after SCI. For example, Moore *et al.*[10] reported that persons with chronic incomplete or complete SCI have 14%-32% lower muscle cross sectional area in the calf than controls. Moreover, lower extremity fat deposition is up to fourfold higher in SCI versus able-bodied persons[11], and there is a loss of lean body mass in the trunk and arms[12] that reduces physical function and capacity for day-to-day activities including wheelchair ambulation, all leading to altered quality of life. In addition, visceral adipose tissue is typically higher[13], which increases the risk of cardiovascular disease and diabetes[14,15]. Chronic aerobic and resistance exercise training can modify body composition in SCI, but the majority of data showing positive effects are from studies employing lower extremity functional electrical stimulation (FES) using leg cycling[16], resistance training[17], or subtetanic contractions[18,19] that are often inaccessible for people with SCI. Recent studies show no change in body composition in response to completion of chronic upper-body resistance training[13] or arm ergometry[20], two widely-used exercise modes in this population. Consequently, a recent review[21] concluded that there is insufficient evidence to support exercise training to modify body composition in SCI.

One rehabilitation modality frequently used in this population is activity-based therapy (ABT), which targets activation of the neuromuscular system below the injury level, with a goal of retraining the nervous system to recover a specific motor task such as locomotion[22]. Institution of ABT using modalities including load bearing, locomotor training, resistance training, and/or FES typically targets the paralyzed or partially paralyzed muscles and may also aid in prevention or treatment of various secondary health complications seen after SCI. In a randomized controlled trial, Jones *et al.*[23] showed that ABT significantly improved walking-related outcomes in persons with incomplete SCI. Nevertheless, exercise training such as ABT requiring voluntary contractions may have a lesser ability to modify body composition[24,25], although this is not universal[26]. Therefore, it is unclear if body composition can be modified with voluntary exercise in SCI such as ABT, and if any change in body composition is consequent with a change in quality of life. If ABT does not elicit changes in body composition, alternative exercise modalities may need to be implemented to improve this outcome in this population.

The current study examined effects of chronic ABT on perceived quality of life, pain, body satisfaction, and body composition in persons with SCI, which are related to subjective well being. Data from a recent review[27] of four studies containing 139 participants indicated no effect of ABT on quality of life, yet most included studies were of low quality. Data from Dolbow *et al.*[28], Sharif *et al.*[29], and Sadowsky *et al.*[30] show greater quality of life after FES training, yet it is unknown if similar results can occur with multi-modal ABT. It was hypothesized that ABT would improve measures of quality of life and body satisfaction, but not pain, fat free mass (FFM), or fat mass (FM) in men and women with SCI. Resultant data can be used towards identifying effective rehabilitation strategies targeting these outcomes, which are associated with physical and psychological function and overall well-being of persons with SCI.

METHODS

Design: this study was a within-subjects longitudinal project

Participants initiated 6 months of exercise training, which was continuously supervised by personnel trained in SCI rehabilitation at a local ABT facility. During a single session at baseline and at three and six months, a survey was completed to assess variables including body satisfaction, pain, depression, and quality of life, and participants underwent dual-energy X-ray absorptiometry (DXA) scans to determine whole body and regional body composition. This session was overseen by the primary investigator. In addition, a four-day food log was completed. Assessments were performed a minimum of 18 h after their last training session. Time of day was maintained across all trials within participants. Compliance to training was monitored each day by staff at the facility.

Participants

Twenty-nine men and women with SCI were initially recruited and subsequently initiated this study; they were recruited by word-of-mouth. They comprised a convenience sample of patients completing ABT at a local rehabilitation facility. Eighteen individuals were identified as Caucasian, six as Hispanic, three as Middle Eastern, and two as African-American. Initially, participants' health history was examined with a brief survey to ensure they met these inclusion criteria: complete or incomplete SCI, injury level lower than C2, non-ventilator dependent, and physician's permission to engage in an intense exercise program. Prospective participants were excluded if they completed regular ABT (locomotor training, assisted/unassisted walking, *etc.*) in the preceding 12 months or were unwilling to abstain from additional exercise other than wheelchair ambulation outside the study; lacked the physical function or had excess pain to complete training; were taking medications altering body composition or mental status (such as testosterone, antidepressants, and/or diabetic and/or cardiovascular drugs) other than calcium or vitamin D supplements; had medical conditions besides paralysis that alter body composition, such as diabetes or hyperthyroidism; were peri- or post-menopausal; or suffered an acute infection. Participants provided informed consent to participate in the study, which was approved by the University Institutional Review Board and was conducted in accordance with the Declaration of Helsinki.

Assessment of quality of life

Using an interview format, the primary investigator read each item to the participant and recorded his/her response, as not all participants could use pen and paper. Initially, the 10-item body satisfaction survey (BSS)[31] was completed, with scores ranging from -3 (very dissatisfied) to +3 (very satisfied). This survey has a range of scores from -30 to +30 and included questions pertaining to physical function (seven items) and appearance (BSS-A) (three items), which were scored separately. Next, participants were asked "how much bodily pain have you had in the last four weeks" and "how much did pain interfere with your normal work/day-to-day activities", which were scored from 1 (none) to 6 (very severe). These were taken from the Short Form-36 survey (SF-36) scale[32] and have been previously utilized in SCI[2]. The 11-item PQOL scale[2] containing four additional items related to quality of life in SCI[33] was then completed, in which participants were asked their degree of satisfaction on a scale of 0-100.

Subsequently, we asked participants questions regarding the severity of onset of secondary complications commonly seen in SCI including spasms, joint stiffness, constipation, urinary tract infection, pain, *etc.*, using the following scale previously developed in this population[34]: (1) "I don't have this problem"; (2) "Problem is not at all bothersome"; (3) "Problem is slightly bothersome"; (4) "Problem is moderately bothersome"; and (5) "Problem is greatly bothersome".

Lastly, the Center for Epidemiological Studies Depression scale[35] was completed. Participants were asked to rank on a 0 (rarely or none of the time) to 3 (most or all of the time) scale how they felt about each of 20 items during the last week. The overall score was the sum of all 20 items for a total possible score equal to 60. This survey is reliable and valid in persons with SCI[36].

Assessment of body composition

Participants arrived at the laboratory after an overnight fast (> 10 h) wearing exercise attire without metal. Initially, the participant was placed on the dual-energy X-ray absorptiometer (DXA software version 13.5, Lunar Prodigy Advance, GE Healthcare, Madison, WI, USA) for a few minutes to minimize muscle spasm. They were instructed to remain motionless and not talk during the scan, which was used to estimate whole-body and regional (arm, trunk, and legs) FM and FFM. Body weight (in kg) was calculated from the summation of FM, FFM, and bone mineral content. Body composition changes during the study were expressed in absolute units (kg). Analyses were performed by the same technician who followed standard quality control procedures developed by the manufacturer. Intraclass correlation coefficients and coefficients of variation for whole-body and regional determinations of FM and FFM obtained in five individuals with SCI measured three months apart were equal to 0.98 and 0.99 and 0.7% and 0.8%, respectively. In addition, waist circumference was obtained in duplicate in the supine position according to standardized procedures[37].

Assessment of dietary intake

Participants completed a four-day food log (including two weekend days) at baseline and at three and six months. They were encouraged to actively report all food and drink ingested (including supplements) each day with specific instructions to describe method of preparation, portion sizes, and brands where applicable. This information was reviewed during each visit and used to determine total caloric intake as well as fat, carbohydrate (CHO), and protein intake (in g) using a commercially-available website (http://ndb.nal.usda.gov/ndb/foods/list). They were asked to maintain their dietary practices during the study.

Intervention

Participants performed 2-3 h sessions of supervised ABT targeting the lower extremities (80% for those with tetraplegia and 100% for paraplegia) a minimum of two days/week to a maximum of five days/week. Activity-based therapy was shown to enhance motor gains in persons with chronic SCI[38]. This regimen elicits energy expenditure between 5 and 8 mL/kg/min[39], which is similar to circuit training and FES leg cycling[40,41] yet lower than arm ergometry, wheelchair ambulation[40], or exoskeleton-assisted walking[42]. ABT as performed in the current study consisted of these modalities as previously described[38,43]: 1.5-2.0 h/week of active assistive exercise, 1.5 h/week of upper/lower body and core resistance training, 1 h/week of load bearing, 30 min/week of arm/cycle ergometry, 1.0-2.0 h/week of gait training including assisted and unassisted walking as well as body weight-supported mechanized elliptical training, 10-30 min/week of vibration training, and 30 min/week of FES of the quadriceps, gluteals, and hamstrings. Training was individualized for each client based on their baseline function, and progression was instituted daily based on participant tolerance to training and level of adaptation. During the study, time performing active assistive exercises and passive gait training generally decreased while time performing resistance training and active gait training increased. Training volume differed across participants as rehabilitation costs were paid out-of-pocket.

Table 1. Physical characteristics of participants completing six months of activity-based therapy (*n* = 25)

Parameter	Mean (SD)	Range
Age (year)	35.8 ± 12.9	18-59
Height (cm)	178.7 ± 7.1	158-188
Mass (kg)	77.0 ± 13.1	53.7-101.0
DOI (year)	3.8 ± 5.5	0.2-10.0
Complete/incomplete	9/16	NA
Tetraplegia/paraplegia	12/13	NA
Injury level	NA	C5-L1
Gender (male/female)	22/3	

SD: standard deviation; cm: centimeters; kg, kilograms; DOI: duration of injury; NA: non-applicable

Data analysis

Data are reported as mean ± standard deviation (SD) and were analyzed using SPSS Version 20.0 (Chicago, IL). Initially, normality of all variables was examined. Two-way (one within-subjects factor representing training (zero, three, and six months) and one between-subjects factor including injury completeness, severity, and duration of injury as well as training volume) analysis of variance with repeated measures was used to examine changes in all variables in response to training. Overall, data were combined across participants as there were few baseline differences or group × time interactions in most outcome measures when variables including duration of injury, injury completeness, or injury severity were considered. The Greenhouse-Geisser correction was used to account for the sphericity assumption. If a significant *F* ratio was obtained, Tukey's *post hoc* test was used to identify differences between means. Partial eta-squared (η^2_p) was used as an estimate of effect size. Multiple regression was used to examine predictors of the change in body satisfaction and quality of life. Statistical significance was set at $P < 0.05$.

Data availability statement

De-identified data from this study are available upon request.

RESULTS

One woman and three men dropped out after one month ($n = 2$) and five months ($n = 2$) due to injury unrelated to training and moving out of the area. Our results are from 22 men and 3 women who completed six months of ABT and were assessed at baseline and at three and six months of training. Fourteen participants were within one year post-SCI. Participants' injury level included C5-C6 ($n = 7$), C4 ($n = 3$), T3-T4 ($n = 5$), T6-T10 ($n = 4$), T11 ($n = 1$), T12 ($n = 4$), and L1 ($n = 1$). Participant characteristics are demonstrated in Table 1. Adherence to training was equal to 100%. Training volume across participants ranged 4-17 h/week, with a mean value equal to 8.5 ± 4.3 h/week. However, when training volume was used as a between subjects factor in all analyses, there was no effect ($P > 0.05$) of this factor on our outcomes. Where applicable, we separated participants by low (< 8 h/week, $n = 14$) and high volume of ABT (> 8 h/week, $n = 11$).

Change in body satisfaction and pain in response to ABT

The results show a main effect of training on BSS ($P = 0.03$, $\eta^2_p = 0.13$) in that it increased during the study. *Post hoc* analyses showed that the six-month score was higher than at baseline by 0.60 (Table 2, d = 1.0). When injury completeness was used as a between-subjects factor, there was a main effect of training ($P = 0.04$, $\eta^2_p = 0.13$) and training × completeness interaction ($P = 0.02$, $\eta^2_p = 0.15$). *Post hoc* analyses showed that BSS increased from baseline to six months of training in persons with incomplete SCI (-0.87 ± 1.30 *vs.* +0.38 ± 1.40, d = 1.5) but not in complete SCI (0.68 ± 1.63 *vs.* 0.78 ± 1.32, d = 0.1). For BSS-A, there was a main effect of training ($P = 0.01$, $\eta^2_p = 0.17$) and *post hoc* analyses showed that three- (+0.8, d = 0.8) and six-month values (+0.9, d = 0.8) were greater than baseline. BSS-A was higher in persons with paraplegia versus tetraplegia ($P = 0.02$, $\eta^2_p = 0.19$), although no training × group interactions were found across injury duration, severity, or completeness. Pain was unchanged ($P = 0.67$) in response to training.

Table 2. Changes in indices of quality of life (mean ± SD) in response to six months of activity-based therapy in persons with SCI

Parameter	Zero months	Three months	Six months
BSS	-0.36 ± 1.62	0.22 ± 1.48	0.44 ± 1.38*
BSS-A	-0.82 ± 1.59	-0.01 ± 1.80*	0.04 ± 1.54*
PQOL	60.4 ± 18.2	59.7 ± 19.8	64.5 ± 20.6a
CESD	21.3 ± 6.9	20.8 ± 5.7	19.7 ± 5.3
Pain	4.5 ± 1.3	4.4 ± 1.4	4.5 ± 1.3
Don't have secondary complications (%)	48.1 ± 16.8	41.9 ± 21.7	43.0 ± 18.6
Bothersome secondary complications (%)	7.2 ± 9.9	4.4 ± 7.4	3.6 ± 5.6

BSS: body satisfaction survey; BSS-A: body satisfaction survey - appearance; PQOL: perceived quality of life; CESD: Center for Epidemiological Studies depression scale; SCI: spinal cord injury; SD: standard deviation. *$P < 0.05$ *vs.* zero-month value; [a]$P < 0.05$ *vs.* three-month value

Change in perceived quality of life and depression in response to ABT

Perceived quality of life differed with training ($P = 0.04$, $\eta^2_p = 0.11$) and *post hoc* analyses showed that the six-month value was higher than at three months [Table 2] by approximately five units (d = 0.8). Change in PQOL from baseline to six months was higher in persons with acute (+7.6 ± 12.9) or incomplete injury (+7.5 ± 11.2) compared to chronic (+0.7 ± 7.4) or complete injury (+0.9 ± 11.6), although it failed to reach significance ($P = 0.10$). The results show no change in depression ($P = 0.30$) from baseline to six months and there were no effects of injury level, completeness, or volume of physical activity on this response.

Regression data

Various two-predictor models were developed to identify the best predictors of change in PQOL and body satisfaction in response to training. A model ($r = 0.63$, $F = 7.05$, $P = 0.004$) consisting of age ($r = -0.41$, $P = 0.02$) and change in pain ($r = -0.48$, $P = 0.007$) explained 39% of the variance in change in PQOL. Although percent body fat was correlated with change in BSS ($r = 0.33$, $P = 0.049$), no significant models were found. For change in BSS-A, a significant model ($r = 0.504$, $F = 4.08$, $P = 0.03$) consisted of body fat ($r = 0.36$, $P = 0.03$) and baseline pain ($r = 0.27$, $P = 0.08$).

Change in body composition in response to ABT

Body composition results are revealed in Table 3. Body mass ($P = 0.30$) did not change but %BF (body fat) increased ($P = 0.02$, $\eta^2_p = 0.17$) from baseline to six months by 1%. Whole-body FFM did not change across time ($P = 0.11$), but there was a training × group interaction in that it declined by approximately 2 kg in individuals with complete SCI ($n = 9$, 50.8 ± 7.9 kg to 48.7 ± 7.0 kg), but did not change in participants with incomplete injury ($n = 16$, 47.7 ± 7.4 kg to 47.5 ± 7.5 kg). Leg FFM ($P = 0.88$), leg %BF ($P = 0.08$), and waist circumference ($P = 0.80$) were unchanged during the study. There was a tendency for trunk FFM to decline during the study ($P = 0.06$). Trunk %BF increased ($P = 0.03$), and *post hoc* analyses showed that three- and six-month values were higher by 1.2%-1.3% than at baseline. There were no differences in arm FFM ($P = 0.20$) or %BF ($P = 0.13$) during the study. Arm FFM was higher ($P = 0.003$) in persons with paraplegia versus tetraplegia. From baseline to six months of training, whole-body %BF declined by more than the coefficient of variation of the measure in 24% of participants, and 32% of participants showed increases in whole-body FFM.

Change in dietary intake

Data revealed that total energy intake declined from baseline (1769.1 ± 349.3 kcal, 1650.3 ± 410.4 kcal, and 1660.9 ± 366.9 kcal, $P = 0.03$), whereas fat (64.9 ± 15.0 g, 59.7 ± 15.8 g, and 60.6 ± 16.2 g, $P = 0.20$), CHO (211.6 ± 53.0 g, 197.2 ± 53.6 g, and 201.0 ± 54.5 g, $P = 0.17$), and protein intake (78.3 ± 21.1 g, 80.6 ± 26.0 g, and 74.2 ± 28.5 g, $P = 0.27$) were unaltered.

Table 3. Changes in body weight and body composition (mean ± SD) in response to six months of activity-based therapy in persons with SCI

Parameter	Zero months	Three months	Six months
Mass (kg)	76.3 ± 13.2	77.1 ± 13.1	77.0 ± 13.4
Whole-body FFM (kg)	48.8 ± 7.9	48.6 ± 7.4	47.9 ± 7.2
%BF	32.7 ± 12.2	33.6 ± 11.7*	33.8 ± 11.2*
WC (cm)	91.0 ± 13.0	90.7 ± 14.6	90.1 ± 13.4
Leg FFM (kg)	14.3 ± 3.0	14.3 ± 3.1	14.3 ± 2.9
Leg %BF	36.4 ± 11.9	37.3 ± 11.3	37.5 ± 10.8
Trunk FFM (kg)	24.2 ± 3.6	23.9 ± 3.3	23.6 ± 3.4
Trunk %BF	33.4 ± 13.5	34.6 ± 13.4*	34.7 ± 12.7*
Arm FFM (kg)	6.1 ± 1.9	6.3 ± 1.8	6.3 ± 1.9
Arm %BF	27.1 ± 13.7	27.6 ± 14.3	28.6 ± 13.2

kg: kilograms; FFM: fat-free mass; BF: body fat; WC: waist circumference; SD: standard deviation; SCI: spinal cord injury. *$P < 0.05$ *vs.* baseline

DISCUSSION

Despite no significant improvements in FFM or FM, bodily pain, or depression, individuals with SCI undergoing six months of ABT revealed small but significant increases in PQOL and body satisfaction. Although our data cannot explain what led to this improved quality of life, previous reports indicate that exercise improves sense of control and mastery that people have regarding their physical function[44]. Due to the potential link between quality of life and exercise participation in SCI[3], structuring exercise programs targeting these outcomes may help promote exercise adherence in this population.

Supporting our findings, improved PQOL has been reported in response to exercise training in SCI. In men and women at least one year post-SCI[4], nine months of resistance training and arm cycling improved PQOL, which was coincident with reduced pain, depression, and greater muscle strength and arm cycling performance that, in turn, might elicit an improved mental health profile. Similarly, improved PQOL occurred in patients undergoing 12 weeks of FES ambulation training despite no change in depression[29]. Nevertheless, in persons with complete SCI, 18 months of incorporation of ABT into daily activities had no effect on functional independence or quality of life (measured with the Short Form-36)[45]. Jones *et al.*[23] reported no change in quality of life despite increased walking speed in men and women with incomplete SCI undergoing six months of ABT. Potential explanations for no change in PQOL can be due to a ceiling effect or inclusion of participants with varying injury duration, as persons with chronic SCI may come to terms with their injury and may believe that it no longer alters their quality of life. Alternatively, we had many individuals within one year of injury who likely struggle with the challenges of acute SCI and report a low quality of life. Our ABT regime was also held in a facility providing social interactions to clients that also may enhance PQOL.

In 695 men and women with SCI[3], a greater incidence of pain and depression and lower life satisfaction was found in overweight versus normal weight individuals, likely due to greater difficulty in completing activities of daily living. Previous studies also suggest that body satisfaction may be higher[46] or lower[47] in persons with greater physical activity. Our body satisfaction values are lower than those reported in men approximately 15 years post-SCI[48], likely due to their more recent injury status and higher levels of body fat. Similar to our findings, 10 weeks of exercise training in a heterogeneous group of men and women with SCI improved functional and appearance-related body satisfaction[49]. Overall, various modes of exercise including ABT have the potential to improve body satisfaction in persons with SCI. Because of our small sample and lack of a control group, our results showing enhanced body satisfaction are preliminary and require further study to confirm.

Our results show no change in bodily pain, which may be due to the fact that many participants reported no or minimal pain at baseline. This finding opposes previous results; for example, in individuals with chronic SCI, 12 weeks of FES-ambulation training reduced bodily pain[29], similar to findings seen in response to nine months of resistance/aerobic training[4]. In persons with paraplegia, four months of circuit training reduced shoulder pain, which was consequent with increased total body strength[50]. In addition, a single bout of locomotor training may reduce pain perception in persons with incomplete SCI[51]. However, findings from one study[5] demonstrated no change in pain after nine months of aerobic and resistance training, which was seen as a positive response considering that non-exercising controls showed greater pain. Baseline pain was also associated with change in BSS-A, and our participants' change in pain was a significant predictor of change in PQOL, which supports previous findings[3]. As pain is related to exercise adherence[3,52], mobility[53], and onset of depressive symptoms[54], rehabilitation and fitness professionals should consider this outcome when treating persons with SCI who have elevated pain.

In the present study, we used the Center for Epidemiological Studies Depression scale to assess potential changes in depression in response to ABT. It is evident[55] that scores above 16 may identify individuals at risk for clinical depression. Although our participants' scores declined by two units from baseline to six months, this change was not significant. Our heterogeneous sample may have been too small to detect changes in depression considering that greater than 40 participants may be needed for adequate statistical power[55]. Moreover, examination of change in depression with between-subjects factors equal to injury severity, duration, completeness, and volume of training did not reveal any differences between groups. In another study[4], fewer depressive symptoms were noted after nine months of exercise training in individuals with SCI compared to non-exercising controls, although their baseline score did not indicate clinical depression and, in addition, the value did not increase from pre- to post-training.

Our data do not support the efficacy of ABT to improve body composition measured via DXA, as whole body and regional %BF increased and there was no change in FFM [Table 3]. However, the observed increase in %BF is minimal and may not be clinically meaningful in regards to enhancing risk of comorbidities associated with SCI. In contrast, decreased FM and increased FFM occurred[17,19] when long-term FES is performed by persons with acute as well as chronic paraplegia and tetraplegia. There are a few explanations for the lack of change in body composition in response to ABT. First, our ABT regime required more core and upper-body resistance training than exposure to FES, which may minimize potential for muscle hypertrophy. Second, energy expenditure of ABT is lower than other exercise modes[40], which may be insufficient to induce negative energy balance and thus weight or fat loss. In the present study, 56% of participants were less than or equal to 1 year post-injury, during which there is a considerable loss in FFM and rise in FM[56], and it could be that our minimal changes are a result of continued changes in body composition that were not slowed by our intervention. Third, despite wide use of DXA to assess body composition[16,57] and data showing DXA-derived increases in FFM and/or decreases in regional body fat in SCI in response to electrical stimulation training[19,58], its ability to detect small changes in FM or FFM after exercise training is less than magnetic resonance imaging. It is plausible that DXA should only be used in studies when relatively robust changes in energy balance and/or body composition are expected, such as those using high-volume FES-based exercise or manipulation of both exercise and dietary intake to improve health status in this population. Fourth, individual variability in these responses occurred, as FFM declined in persons with complete injury and was unchanged in men and women with incomplete injury. Overall, by itself ABT does not seem to induce significant changes in body composition, especially in persons with acute injury.

Our study had a few limitations. We used a convenience sample composed of individuals who were already completing ABT at the facility. A non-exercising control group was not recruited, thus we are uncertain if the changes seen in this study are truly due to exercise training. Participants differed in injury duration,

severity, and completeness that may reduce our ability to gauge the efficacy of ABT, especially in persons with acute SCI who are experiencing changes in body fat and FFM. However, in a previous study[4], regular physical activity improved various physical and psychological outcomes in persons with SCI irrespective of their level or completeness of injury. The Short Form-36 is widely used in populations including SCI to monitor changes in health-related quality of life[29]. However, other than its two pain-related items, we did not use it as it was found to be too burdensome on our sample. Although all participants received comprehensive ABT, the make-up and volume of said training varied based on participants' existing function, their progress through training, and, lastly, their ability to pay for training, which was not covered by insurance. This requirement to pay for training may have led to more favorable outcomes related to QOL. The latter factor led to different doses of training performed by each participant. However, there was no relationship between weekly volume of training and the change in %BF, FFM, or any of the psychological variables. In addition, the increases in PQOL and body satisfaction were evident irrespective of whether participants completed a low or high volume of ABT. These findings suggest that disparate volumes of training had little impact on our results. In addition, FES comprised a small portion of habitual training, which may have led to the non-significant changes in body composition. However, our study is strengthened by a sample size that is greater than those used in most studies examining PQOL. Our sample included persons of varied injury level and injury duration, which allows generalization of our findings to the entire population with SCI rather than one homogeneous group. In addition, we tracked food intake through dietary logs, and data showed minimal changes in energy intake during the study, which gives us greater confidence that observed changes in body composition were not due to variations in dietary patterns.

In conclusion, Six months of ABT slightly improved various indices of quality of life but did not induce changes in body fat or FFM. Pain was also associated with the changes in quality of life and body satisfaction observed in response to training. The changes seen in this study are small. Due to our small and heterogenous sample recruited by convenience, lack of a control group, and non-standardized training regimen, additional work is needed to confirm these data. Future studies should explore the potential for alternative modalities of exercise to enhance quality of life due to its relationship with exercise adherence in SCI.

DECLARATIONS

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Authors' contributions

Conceived the study: Astorino TA, Harness ET
Analyzed the data and wrote the final draft of the manuscript: Astorino TA, which Harness ET reviewed
ETH supervised all training sessions; whereas: Harness ET
Supervised all assessments: Astorino TA

Availability of data and materials

De-identified data could be made available to readers upon request.

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Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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