Body composition modifications in people with chronic spinal cord injury after supervised physical activity

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Background: Quantification of body composition variables is important for planning of better activities in relation to individuals with spinal cord injury (SCI).

Objectives: (1) To evaluate changes in body composition in patients with SCI after a supervised physical activity process; (2) To correlate total body fat with time since injury.

Design: Pre-post intervention.

Setting: Sarah Rehabilitation Hospital Network, Brazil.

Participants: Fifty-three men with SCI aged 18–52 years with duration of injury >3 years.

Interventions: The subjects were divided into three groups: tetraplegia (TT) (C5–C8), high paraplegia (HP) (T1–T6), and low paraplegia (LP) (T7–L2). Body composition was estimated in the first and last weeks of hospitalization.

Outcome measures: Body weight (kg), skinfolds sum (mm), absolute (kg), and relative (%) fat and lean body mass.

Results: Body weight increased in TT and decreased in HP (0.8 kg, 95%CI 0.1–1.5; and –1.0 kg, 95%CI –2.0 to 0.0, respectively; $P < 0.05$). Skinfolds sum decreased only in HP (–13.1 mm, 95%CI –20.7 to –5.5; $P < 0.05$). Absolute and relative body fat decreased significantly in the paraplegia groups. Lean body mass (LBM) percentage increased significantly in the paraplegia groups. Absolute LBM increased in TT and LP (0.8 kg, 95%CI 0.3–1.3; and 1.3 kg, 95%CI 0.8 to 1.8, respectively; $P < 0.05$). There was no correlation between time since injury and skinfolds sum for the three groups ($P < 0.05$).

Conclusion: TT, HP, and LP demonstrated favorable changes in body composition after 29 days of supervised physical activity. However, these changes were different in direction and magnitude.

Keywords: Tetraplegia, Paraplegia, Body composition, Exercise, Body fat, Rehabilitation, Spinal cord injuries

Introduction

Body composition assessment is the analysis of the distribution of different tissues, organs, and organism components.^{1–4} Determination of the proportion between lean body mass (LBM) and fat mass is an important predictor of cardiovascular disease, type II diabetes, and dyslipidemia. Moreover, this relation indicates characteristics related to performance in physical activities, and a change in the relation demonstrates the physiological training responses.^{1–7}

There are several ways to measure body composition. Although not the gold standard, dual-energy X-ray absorptiometry (DEXA) is the measurement technique

used as a reference for evaluating other methods of determining body composition.⁵ However, this assessment is not practical and accessible in the usual clinical evaluations. The measurement of skinfolds, because of its practicality, is a widely used technique and shows good correlation with hydrostatic weighing, which is considered the gold standard in healthy subjects.^{1–5,7–11} For patients with spinal cord injury (SCI), hydrostatic weighing has some limitations. Besides the difficulty of implementation for this population, the precision of the method can be confounded by accelerated bone density loss and relatively high residual volumes due to the inability to exhale fully in higher lesions.

In healthy subjects, the proportion of body composition components is different from that used for body density calculations in patients with SCI.^{5,8–10,12}

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Several studies have demonstrated a reduction in bone mass,^{5,13} muscle,^{5,14–16} amount of body water,¹⁷ and an increase in body fat^{5,13} in this population. Indeed, a high obesity prevalence was demonstrated in adolescents with SCI.¹² Obese youth have a greater tendency to become obese adults,³ and in addition to correlation with metabolic syndrome risk factors (glucose intolerance, hyperlipidemia, hypertension), obesity compromises ambulation, transfers, and increases the risk of bedsores and surgery risks.^{12,18}

For these reasons, fat percentage formulas are not well correlated with the gold standard, although they are used in clinical studies in SCI.^{8,10,11,19–22} This limitation makes the measurement useful only for comparative intra-subject analysis and not for longitudinal analyses with reference values. Some authors suggest using the skinfolds sum as another parameter in this type of analysis.^{1,9}

Quantifying body composition variables and associating them with the functional level and the SCI patient's responses in a rehabilitation process are important for better activities planning and adequate training monitoring, in addition to being used as patient-motivating features and as a reference to monitor metabolic parameters.²³

The objectives of this study were: (1) to determine body composition changes in SCI patients during hospitalization at the Sarah Network of Neuroscience and Rehabilitation International; (2) to compare changes in body composition at different levels of motor impairment; (3) to examine the differences in body composition between different SCI levels; and (4) to correlate the proportion of body fat with time since injury.

The hypothesis of this study is that there are positive body composition changes in SCI patients after a supervised physical activity program. These changes differ according to injury level.

Methods

Subjects and settings

Fifty-three men with SCI were selected, consecutively, from October 2007 through December 2009. They were hospitalized in a program at the Sarah Network of Rehabilitation Hospitals (Lago Norte, Brasília) and underwent body composition assessment (pre-post intervention). These assessments are part of the treatment program, helping in decision-making guidance to practice regular physical activity. Patients were hospitalized for rehabilitation to improve their independence in daily living, for medical follow-up, and to be instructed in sports and physical activities to continue after

discharge. This study was approved by the ethics committee of the Sarah Hospital (no. 709).

Inclusion criteria: men aged over 18 years, diagnosed with SCI, and released by the medical team to proceed with the supervised physical activity program without restrictions.

Exclusion criteria: patients who could not be assessed for any reason, for example, difficulty in positioning for evaluation.

Patients were classified according to the American Spinal Injury Association (ASIA) classification.²⁴ The neurological level was collected from electronic medical records. For analysis, patients were categorized into three groups: tetraplegia (TT) – C4–C8; high paraplegia (HP) – T1–T6; and low paraplegia (LP) – below T7. The division of the first group from the other two results from the TT ASIA classification and the involvement of the upper limbs.²⁴ The separation of the second and third groups results from the changes arising from the sympathetic nervous system and trunk instability. This division criterion is commonly used in studies of SCI.^{22,25–28}

The ASIA Impairment Scale (AIS) varied from A to D. Ambulatory status: 49 were wheelchair users, 3 were canes users, and 1 alternated canes and wheelchair. Due to the small number of patients with incomplete injuries ($n = 19$), the impairment comparison (AIS) was done with the whole sample. The sample characteristics are shown in Table 1.

Anthropometric measures

Skinfolds used were biceps, triceps, subscapular, chest, midaxillary, suprailiac, abdominal, thigh, and calf in accordance with previous standardization.^{1,2} In accordance with the Bulbulian protocol,⁸ measurements of trunk, and upper limbs were made sitting in a wheelchair with the lower limbs in a supine position. All measurements were collected on the patient's right side. The skinfolds were collected consecutively and then a second measurement was acquired. The average was used as the final value. In case of a difference of >5% between the two measures, a third was performed and the median was used as a final result.¹

The body weight was calculated by subtracting the wheelchair weight from the total weight (patient plus wheelchair). Height was measured in the supine position.

Procedures

The evaluations were performed by same assessor, part of investigative team, in the first and last weeks of hospitalization. In this study, body weight (kg), skinfolds sum

Table 1 Sample characteristics with mean and standard deviation

	TT C4–C8	HP T1–T6	LP T7–L2	Total
<i>n</i>	20	15	18	53
AIS				
A	8	13	13	34
B	6	1	2	9
C	4	–	2	6
D	2	1	1	4
Age (months)	24.0 (±7.5)	27.3 (±7.9)	30.1 (±8.5)	27.0 (±8.2)
Height (cm)	178.1 (±6.3)	173.5 (±6.0)	177.9 (±7.4)	176.7 (±6.8)
TSI (months)	35.5 (±18.5)	39.0 (±21.9)	47.5 (±35.8)	40.5 (±26.5)

No significant difference between TT, HP, and LP groups.

AIS, ASIA Impairment Scale (A = complete; B–D = incomplete; E = normal); TSI, time since injury; TT, tetraplegia; HP, high paraplegia; LP, low paraplegia.

Table 2 Physical activities in a week of hospitalization realized by TT, HP, and LP groups

Physical activities	Times/week	Total time (minute)*	Groups
Bocce	1	45	TT
Canoeing	1	30	TT, HP, and LP
Physical therapy	5	60	TT, HP, and LP
Resistance training	2	45	TT, HP, and LP
Rugby	1	45	TT
Swimming	2	45	TT, HP, and LP
Table tennis	1	45	TT, HP, and LP
Wheelchair basketball	2	90	HP and LP
Wheelchair propulsion physical conditioning	2	30	TT, HP, and LP

*Total time is estimated for each activity.

TT total time physical activity/week: 705 minutes/week.

HP and LP total time physical activity/week: 795 minutes/week.

TT, tetraplegia; HP, high paraplegia; LP, low paraplegia.

(mm), and percentage body fat (%Fat), calculated by the Durnin & Womersley (1962) formula,^{8,10,11,19,21,22} were assessed to compare body composition. This formula includes biceps, triceps, subscapular, and suprailiac skinfolds. With the fat percentage results, the following were also calculated for analysis: (1) fat mass (kg fat): body weight multiplied by the %Fat; (2) lean body mass (kg LBM): fat mass subtracted from body weight; (3) percentage of lean body mass (%LBM): %Fat subtracted from 100% body weight.

Supervised physical activity program

In the interval between assessments, patients participated in multidisciplinary activities that included physical sports and physical therapy, 5 days a week. Physical activities varied in frequency and intensity according to time since injury, injury level, fitness level, and week of hospitalization. However, in general, patients participated in the activities shown in Table 2.

Statistical methods

The distribution of variables was performed by the Komolgorov–Smirnov normality test, as the sample

was >50. The variables demonstrated a normal distribution. Thus, the paired Student's *t*-test was used to analyze the difference between the first and second evaluations. Comparisons of means between groups for age, height, time since injury, and the results of the first evaluation were performed using one-way analysis of variance and, in case of significance, the Bonferroni *post hoc* test. This test reduces the chance of finding unreal differences (type I error). The independent sample *T*-test was used to compare the complete and incomplete lesion. The Pearson correlation was used to examine the relationship between time since injury and the skinfolds sum. Descriptive statistics were used as mean and standard deviation to characterize the results.

The statistical packages SPSS (SPSS Inc., version 13.0) and MedCalc (version 9.0.1.0) were used for data processing. Statistical significance was considered to be $P < 0.05$.

Results

The TT, HP, and LP groups did not differ significantly among for variables fat percentage and LBM

Table 3 First body composition evaluation for total group and subgroups with mean and standard deviation

	Total (n = 53)	TT (n = 20) C4–C8	HP (n = 15) T1–T6	LP (n = 18) T7–L2
Body weight (kg)	68.3 (±12.4)	67.4 (±10.9)	68.2 (±12.8)	69.3 (±14.2)
ΣSF (mm)	158.8 (±71.4)	167.0 (±74.4)	155.5 (±77.5)	152.5 (±65.7)
%Fat	21.3 (±7.0)	21.9 (±7.3)	20.7 (±7.7)	21.0 (±6.3)
kg fat	15.2 (±7.1)	15.4 (±6.8)	14.8 (±7.9)	15.2 (±7.2)
%LBM	78.7 (±7.0)	78.0 (±7.4)	79.3 (±7.7)	79.0 (±6.3)
kg LBM	53.1 (±6.8)	51.9 (±6.0)	53.3 (±6.2)	54.1 (±8.2)

No significant difference ($P < 0.0167$) between TT, HP, and LP groups.

TT, tetraplegia; HP, high paraplegia; LP, low paraplegia; ΣSF, skinfolds sum.

percentage, fat mass and lean body mass, skinfolds sum, and total body weight in the first assessment (Table 3).

Changes in variables during hospitalization are shown in Table 4 and Fig. 1. The TT and HP groups had contrary and significant behavior ($P < 0.05$) regarding body weight: a significant increase and decrease, respectively, (0.8 kg, 95%CI 0.1–1.5; and -1.0 kg, 95%CI -2.0 to 0.0). The fat percentage and the fat mass were reduced in the HP and LP groups (-0.8% , 95%CI -1.4 to -0.2 ; and -0.9 kg, 95%CI -1.5 to -0.3 ; -1.1% , 95%CI -1.9 to -0.4 ; and -0.8 kg, 95%CI -1.6 to -0.1 , respectively; $P < 0.05$), although the skinfolds sum had decreased only in the HP group (-13.1 mm, 95%CI -20.7 to -5.5 ; $P < 0.05$). The relative LBM increased in the HP and LP groups (0.8% , 95%CI 0.2 – 1.4 ; and 1.1% , 95%CI 0.4 – 1.9 , respectively; $P < 0.05$), but in absolute terms, the significance occurred in the TT (0.8 kg, 95%CI 0.3 – 1.3) and LP groups (1.3 kg, 95%CI 0.8 – 1.8) and both of them differed significantly from the HP group ($P < 0.05$).

There was no significant difference between complete and incomplete lesion for all analyzed variables (Table 5). Body weight had no significant change in the second assessment in complete and incomplete groups (0.2 kg, 95%CI -0.5 to 0.8 ; and 1.7 kg, 95%CI -0.7 to 0.9 , respectively). Skinfold sum also had no significant change in incomplete group (-5.4 mm, 95%CI -11.5 to 0.7).

There was no correlation between time since injury and sum of skinfolds ($P > 0.05$) for TT, HP, and LP groups ($r = 0.22$; 95%CI -0.25 to 0.64 ; $r = 0.09$; 95%CI -0.44 to 0.58 ; and $r = -0.04$; 95%CI -0.50 to 0.43 , respectively).

Discussion

Twenty-nine days between the first and second evaluations were sufficient to demonstrate favorable body composition changes in the total group after hospitalization: an increase in LBM and a reduction in skinfolds sum and fat percentage. Only body weight showed no

statistical difference compared with the first evaluation. Thus, associated resistance training and sports are key to positive responses in the rehabilitation process.^{14,16,29–31}

When comparing the subgroups TT, HP, and LP, there was no significant difference for the variables in the first assessment. Similar results were found in another study,²⁰ in which the TT group did not differ from the paraplegia group. However, after the supervised physical activity period, we found different, but advantageous, responses in body composition variables depending on the level of injury.

The fat mass of the TT group did not change, but the skinfolds sum and fat percentage were reduced. This indicates a necessary increase in total lean body mass. The initial fat percentage value of this group is lower than in previous studies. Spungen *et al.*²⁰ described a group of 66 patients with TT and a fat percentage of approximately 33.7%. There are, however, some differences between the groups that may explain this higher value. Spungen's sample group was older (40 years), with longer time since injury (14 years) and higher initial weight (79.2 kg).²⁰ Furthermore, DEXA was the measuring technique and not skinfolds sum. The latter technique has a tendency to underestimate the fat percentage results in a SCI population.¹¹ A study with five tetraplegic patients assessed with DEXA also demonstrated a higher fat percentage value (29.7%).³²

The HP group showed a significant reduction in body weight, skinfolds sum, fat percentage, and fat mass. Regarding the values for lean body mass, a significant increase only occurred in the relative analysis. The LP group, in turn, demonstrated significantly reduced absolute and relative values of fat and increased lean body mass, but an increase in body weight. Some studies used paraplegia as a sample, but not divided between HP and LP.^{5,8,10,19,20} So it was not possible to compare the body composition changes between these groups with the literature.

Different body composition baseline values for this population with similar impairments are found in the

Table 4 Results of difference between first and second evaluations in total group and subgroups with mean difference (MD)*, standard deviation (SD), and interval confidence (95%CI)

	Total			TT			HP			LP		
	MD	SD	95%CI	MD	SD	95%CI	MD	SD	95%CI	MD	SD	95%CI
Rehabilitation days	28.6	±12.3	-	27.6	±14.2	-	31.7	±11.2	-	27.3	±11.1	-
Body weight (kg)	0.2	±1.8	-0.3 to 0.7	0.8**	±1.5	0.1 to 1.5	-1.0****	±1.8	-2.0 to 0.0	0.4****	±1.7	-0.4 to 1.3
ΣSF (mm)	-7.2**	±16.1	-11.6 to -2.7	-0.9	±13.9	-7.4 to 5.6	-13.1**	±13.7	-20.7 to -5.5	-9.1	±18.5	-18.3 to 0.1
%Fat	-0.7**	±1.4	-1.1 to -0.3	-0.2	±1.4	-0.9 to 0.4	-0.8**	±1.1	-1.4 to -0.2	-1.1**	±1.5	-1.9 to -0.4
kg fat	-0.5**	±1.3	-0.9 to -0.2	0.0	±1.0	-0.5 to 0.5	-0.9**	±1.0	-1.5 to -0.3	-0.8**	±1.5	-1.6 to -0.1
%LBM	0.7**	±1.4	0.3 to 1.1	0.2	±1.4	-0.4 to 0.8	0.8**	±1.1	0.2 to 1.4	1.1**	±1.5	0.4 to 1.9
kg LBM	0.7**	±1.2	0.4 to 1.0	0.8**	±1.0	0.3 to 1.3	-0.1***	±1.2	-0.8 to 0.5	1.3*****	±1.0	0.8 to 1.8

*Mean difference corresponds to subtraction of the second for the first evaluation for all variables.

**Significant difference ($P < 0.05$) between first and second evaluations.

***Significant difference ($P < 0.05$) with TT group.

****Significant difference ($P < 0.05$) with HP group.

TT, tetraplegia; HP, high paraplegia; LP, low paraplegia; ΣSF, skinfolds sum.

literature. Studies using skinfolds and the Durnin & Womersley formula showed lower fat percentages, but they were close to the results obtained in this study.^{8,10} Fat percentage values obtained by DEXA were reduced in patients with paraplegia.^{5,12,20,32,33}

Although we found only a partial account of the standardization of anthropometric measurements in individuals with SCI,⁸ the technique was used appropriately in view of the similarity of baseline characteristics and body composition results from samples in these studies and the study conducted here. It must be considered, however, that although it has been used in some articles,^{8,10,11} the Durnin & Womersley (1962) formula is not yet validated.⁸ Thus, the interpretations of ideal standards should be avoided. By using the percentage of fat for this population, other variables must be associated, for example, skinfolds sum. In this way, it is possible to verify body composition changes in an intervention for the same individual or group.

A greater increase in LBM shown in the LP group is possibly associated with a greater preservation of muscle mass. Besides having more preserved muscle (greater amount of protein synthesis) and, consequently, hypertrophy, these patients have a wider availability of choice of physical activities. Therefore, increases in LBM and reduced fat levels in patients with lower level SCI occur with greater magnitude compared with those with higher lesions.^{20,33} It is important, however, to consider that this was the only group in which there was a difference between ΣSF and %Fat. Only the second one had a significant difference and Durnin & Womersley (1962) formula does not consider skinfolds for lower limbs. Changes in spasticity may be an explanation for this result. Lower injuries presents, typically, less spasticity³⁴⁻³⁶ and there are indications that this may reduce fat percentage value.³⁷ Spasticity degree was not evaluated in this study and this possibility should be better investigated.

A stratified analysis according to lesion impairment was performed. There was no significant difference between complete and incomplete injuries. However, Gorgey *et al.*³⁷ reported an increased basal metabolism in individuals with SCI with more muscle mass. This metabolic behavior causes changes in body composition, especially in reducing fat percentage. Possibly, the least amount of patients with incomplete lesions increases the chance of type II errors (unreal equalities). Confirmation of this result is difficult to check in the literature, given that some studies do not specify the injury impairment,^{8,10-12,19,20} other used only complete injury,⁵ and only one was performed in A and B lesions.³² However, the latter did not compare these two groups.

Figure 1 Percentage changes between first and second assessments of the variables body weight, skinfolds sum (mm), percentage body fat (%Fat), fat mass (kg fat), percentage of lean body mass (%LBM), and body mass lean weight (kg LBM) for the sample groups. TT, tetraplegia; HP, high paraplegia; LP, low paraplegia. *Significant difference ($P < 0.05$) between first and second evaluations.

Table 5 Results of difference between first and second evaluations in complete and incomplete groups mean difference (MD), standard deviation (SD), and interval confidence (95%CI)

	Complete lesion ($n = 34$)			Incomplete lesion ($n = 19$)		
	MD	SD	95%CI	MD	SD	95%CI
Rehabilitation days	28.2	12.5	–	29.5	12.2	–
Body weight (kg)	0.2	1.9	–0.5 to 0.8	0.1	1.7	–0.7 to 0.9
ΣSF (mm)	–8.2*	17.8	–14.4 to –2.0	–5.4	12.7	–11.5 to 0.7
%Fat	–0.6*	1.3	–1.1 to –0.2	–0.8*	1.5	–1.5 to –0.1
kg fat	–0.5*	1.3	–1.0 to –0.1	–0.6*	1.2	–1.2 to –0.1
%LBM	0.6*	1.3	0.2 to 1.1	0.8*	1.5	0.1 to 1.5
kg LBM	0.7*	1.2	0.3 to 1.1	0.7*	1.2	0.1 to 1.3

*Significant difference ($P < 0.05$) between first and second evaluations.

No significant difference between complete (AIS A) and incomplete lesions (AIS = B, C, and D) for all variables ($P > 0.05$).

ΣSF, skinfolds sum.

Although an increase in fat percentage was expected with longer time since injury,^{5,13,34–36} similar responses were not found in this study. This expectation is related to decreased physical activity time^{14,38–40} and reduction in active muscle after trauma.^{13,41} Maggioni *et al.*¹⁰ have obtained results similar to ours: no significant correlation between fat percentage and time since injury.

Some limitations should be mentioned. Patients were admitted at different times, which may considerably affect the responses to changes in body composition. Added to this, there was no food control with individual nutritional standards or a comparison with a control group. Finally, although all patients performed physical activities, these were different between groups and individually. Some patients or groups thus presented greater volumes and/or intensity of activity than others (TT group with 705 minutes/week and HP and LP groups with 795 minutes/week). In addition, physical therapy

varies mainly between paraplegia and TT. The first has a greater amount of exercise, including gait training, which increases the total energy expenditure.

Changes in body composition that occurred between the groups are important in supporting the need to adjust the volume and intensity of physical activity and diet during hospitalization. Thus, these data serve to guide an exercise program specific to physical capabilities that correlate with functional independence. It is important, however, to note that these subjects have more than 3 years of duration of injury, when losses in lean tissue have reached their lower points. There are some standards of quantity and quality of exercise to developing and maintaining fitness in healthy adults. This improvement in physical capacity is correlated with a reduction in metabolic syndrome.⁴² Although adjustments can be made for patients with SCI,⁴² there are no specific physical activity patterns for this population.

More studies with a control group of patients with SCI without intervention and a greater restriction of the secondary variables are needed to confirm our findings. Gaps still exist regarding these responses in women and in patients with non-traumatic lesions.

Conclusion

TT, HP, and LP groups presented favorable changes in body composition after a mean of 29 days of supervised physical activity. However, these changes are different in direction and magnitude for each group and it is important to consider that duration of injury is greater than 3 years. Apparently, lower levels of SCI have better responses with respect to gain in LBM and fat loss. However, in this study, there were no differences between the groups in the variables studied, and the amount of body fat was not positively associated with time since injury.

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