Research article

Physical exercise is associated with better fat mass distribution and lower insulin resistance in spinal cord injured individuals

Giselle Louise C. D' Oliveira¹, Flávia A. Figueiredo¹, Magna Cottini Fonseca Passos², Amina Chain¹, Flávia F. Bezerra¹, Josely Correa Koury¹

¹Department of Basic and Experimental Nutrition, Institute of Nutrition, State University of Rio de Janeiro, RJ, Brazil, ²Department of Applied Nutrition, Institute of Nutrition, State University of Rio de Janeiro, Rio de Janeiro, RJ, Brazil

Objectives: The aim of the study was to compare total and regional body composition and their relationship with glucose homeostasis in physically active and non-active individuals with cervical spinal cord injury (c-SCI).

Methods: Individuals with lesion level between C5–C7 were divided into two groups: physically active (PA; $n = 14$; who practiced physical exercise for at least 3 months, three times per week or more, minimum of 150 minutes/week); and non-physically active (N-PA $n = 8$). Total fat mass (t-FM) and regional fat mass (r-FM) were assessed by dual energy X-ray absorptiometry. Fasting plasma insulin (FPI) was determined by enzyme-linked immunosorbent assay.

Results: PA group present lower ($P < 0.01$) total fat mass (t-FM), % and kg, regional fat mass (r-FM), % and kg, FPI levels and HOMA index, while they had higher ($P < 0.001$) total free fat mass (t-FFM), %, and regional free fat mass (r-FFM), %, compared to the N-PA group. In the N-PA group, FPI and HOMA index were negatively ($P < 0.05$) correlated with FFM% ($r = -0.71, -0.69$, respectively) and positively correlated to trunk-FM ($r = 0.71, 0.69$, respectively) and trunk-FM:t-FM (kg) ratio ($r = 0.83, 0.79$, respectively).

Conclusion: Physical exercise is associated with lower t-FM, r-FM, and insulin resistance, which could contribute to the decrease of the risk of cardiovascular and metabolic conditions in individuals with c-SCI.

Keywords: Cervical injury, Insulin, Physical activity, Regional fat mass

Introduction

The incidence of spinal cord injury (SCI) is approximately 12 000 new cases per year in the United States.¹ Cervical lesions represent approximately 55% of cases, and complete lesions affect 56% of individuals.²

Individuals with SCI undergo substantial changes in body composition including increased fat mass (FM) and decreased free fat mass (FFM) as a result of immobilization^{3,4} and impaired sympathetic nervous system.⁵ These changes in body composition can be regional³ and cause many consequences to health.^{4,6} The association between body fat accumulation and the risk of developing diseases is well known by the general

population.^{7,8} However, the correlation between chronic disorders and specifically subcutaneous and visceral fat (VF) has just recently been studied in individuals with SCI.⁹ VF has been considered an independent risk factor for insulin resistance,¹⁰ type 2 diabetes,¹¹ and cardiovascular disease.¹² Large amounts of VF and high VF: subcutaneous fat ratio was observed in individuals with SCI compared to individuals without SCI, matched by age, gender, and waist circumference.¹³

The most effective strategy known to delay these body composition changes is regular physical exercise controlled for frequency, duration, and intensity.¹⁴ Therefore, the evaluation of training programs effectiveness can be determined through the assessment of body composition.

Studies showed that the electrically induced cycle training is associated with increased insulin sensitivity in individuals with chronic SCI.^{15,16} Recently, we

Correspondence to: Magna Cottini Fonseca Passos, Department of Applied Nutrition, Institute of Nutrition, State University of Rio de Janeiro, Rua São Francisco Xavier 524, Rio de Janeiro, RJ 20550-900, Brazil.
Email: magna.cottini@pq.cnpq.br

demonstrated that time of physical exercise practice after injury in men with cervical spinal cord injury (c-SCI) is related to the body fat reduction with consequent increase in insulin sensitivity, which play an important role in preventing cardiovascular disease.¹⁷

Thus, the aim of this study was to compare total and regional body composition and their relationship with glucose homeostasis in physically active and non-active individuals with c-SCI.

METHODS

Subjects

This study was approved by the Ethics Committee of Universidade do Estado do Rio de Janeiro–Brasil (COEP052/2009) and written informed consent from each subject was obtained prior to data collection. Twenty-two male individuals with c-SCI (C5–C7) participated in this study. Participants were examined adopting modified Frankel score, a five-scale subdivision was used: A = complete motor and sensory function disorder; B = complete motor and incomplete sensory function disorder; C = incomplete motor and sensory function disorder; D = useful motor function with or without auxiliary means; E = no motor or sensory function disorder.¹⁸ These individual characteristics are showed in Table 1. Data on physical activity were obtained through a structured questionnaire in which volunteers described the type of physical activity

practiced, the time spent in total daily physical activity (minute), and the time of physical activity practice after injury (months).

The participants were divided into physically active (PA, $n = 14$) and non-active (N-PA, $n = 8$) groups, this was a convenience sample. Individuals were considered as physically active when practicing regular adapted physical exercise according to the following criteria: having a minimum of two and a half hours per week of exercise practice, three times per week or more¹⁴ for at least three months.

Information on causes and duration of injury, age, hours per week of exercise practice and time of continuous practice of physical exercise since injury was collected by trained interviewers using a structured questionnaire. The causes of c-SCI in enrolled participants were as follows: diving accidents ($n = 11$; 50%), motor vehicle accidents ($n = 9$; 41%), and violence ($n = 2$; 9%).

Body composition

Body composition was assessed using dual-energy X-ray absorptiometry (DXA–Lunar, with software enCore 2008 version 12.20, GE Healthcare, WI, USA). Individuals wore lightweight clothing and removed all jewelry. Orthopedic surgical pins or other implants that could affect the scan were identified as artifacts and removed from the analysis. The legs were strapped to the DXA table to ensure there was no spasticity during the scan. A licensed X-ray technologist performed all DXA scans and calibration was made according to the manufacturer's protocol.

A whole-body scan was performed to determine total and regional (arms, trunk, and legs) FM and FFM. Additionally, in order to better investigate the FM distribution trunk-FM:*t*-FM ratio was calculated.

Anthropometry

While lying supine on the DXA table, the individual's length from the top of the head to the bottom of the heel was measured by using a flexible non-elastic measuring tape (Sanny[®], SP, Brazil). Total body mass (kg) was taken as the sum of FM, lean tissue mass and bone mineral content. The body mass index (BMI) was calculated as body weight/height² (kg/m²).

Sample collection and laboratory assay

The individuals were instructed not to eat for 12 hours before sample collection. Blood samples (5 ml) were obtained in the morning (08:00 hours) by venous puncture and placed into tubes containing heparin as anticoagulant (30 U per tube). These tubes were centrifuged at 1800 g for 10 minutes for obtained

Table 1 Individual cervical spinal cord injury characteristics

Participant	Cervical lesion level	Type lesion	Frankel grade
Physically active			
1	7	Incomplete	C
2	6	Incomplete	C
4	5	Incomplete	E
5	5	Complete	A
6	5	Incomplete	C
7	5	Incomplete	C
13	7	Incomplete	D
18	6	Incomplete	C
20	6	Incomplete	C
21	7	Incomplete	D
23	5	Incomplete	C
24	6	Incomplete	C
25	5	Complete	A
Non-physically active			
3	5	Incomplete	C
9	6	Incomplete	C
10	7	Incomplete	D
11	5	Incomplete	C
12	5	Complete	A
14	5	Incomplete	C
15	5	Incomplete	C
16	5	Complete	A
17	5	Incomplete	B

plasma. Blood samples were stored at -20°C until analysis. Fasting plasma glucose (FPG) was measured by enzymatic colorimetric assay (Gold Analyzes, RJ, Brazil; kit reference value was 80–110 mg/dl) and fasting plasma insulin (FPI) by human ELISA kit (EMD Millipore, MA, USA). The homeostasis model assessment for the insulin resistance (HOMA2-IR) index was calculated using the HOMA calculator.¹⁹

Statistical analysis

Normality of distribution for the continuous outcome variables was tested using the Kolmogorov-Smirnov test. Data are expressed as mean $\pm$ standard deviation (SD). Comparisons between active and non-active groups were performed by unpaired *t*-tests. Pearson correlation performed the relationship between body composition and plasma glucose, insulin and HOMA-IR. Statistical analyses were performed for using SPSS for windows v.12.0 and *P* values ≤ 0.05 were considered significant.

Results

The age, length, and duration of injury were similar between PA and N-PA groups. Body weight and BMI were significantly lower ($P < 0.05$) in the PA group. The time of continuous practice of physical exercise since injury in active group was on average 14 ± 10 months with 13 ± 7 hours/week of exercise practice (Table 2).

The PA group had 39% lower total FM ($P < 0.001$) and 48, 23, and 48% lower FM in arms ($P < 0.001$), legs ($P < 0.04$), and trunk ($P < 0.001$), respectively, compared to N-PA group. FFM represented an average of 70% of total body composition for all individuals. There were no differences in FFM (kg) between the groups but the PA group presented higher

FFM percent on arms ($P < 0.001$), legs ($P = 0.005$), trunk ($P < 0.001$), and total ($P < 0.001$) compared to the N-PA group. The trunk FM:t-FM ratio showed that trunk FM corresponded to 58% of the total FM in N-PA group and 49% in PA group (Table 3).

FPG was similar in PA and N-PA groups. The PA group showed significantly lower ($P < 0.05$) FPI levels and HOMA index (Table 4).

The associations between t-FM and FPI and HOMA; and between r-FM and FPI and HOMA in all participants ($n = 22$) and in each group were shown in Table 5. Considering all participants, FPI levels, and HOMA-IR were positively associated with t-FM ($r = 0.59$, $P = 0.004$; $r = 0.58$, $P = 0.004$, respectively), r-FM (arms $r = 0.53$, $P = 0.012$; $r = 0.51$, $P = 0.015$, respectively; trunk $r = 0.61$, $P = 0.003$; $r = 0.59$, $P =$

Table 3 Fat mass distribution obtained by DXA and comparison between non-physically active and physically active groups

	Non-physically active ($n = 8$)	Physically active ($n = 14$)	<i>P</i>
<i>Fat mass (%)</i>			
Total	35.2 ± 4.9	24.2 ± 5.8	<0.001
Arms	26.8 ± 5.5	16.0 ± 4.8	<0.001
Legs	34.9 ± 5.0	27.5 ± 5.3	0.004
Trunk	39.5 ± 6.3	25.0 ± 7.9	<0.001
<i>Fat mass (kg)</i>			
Total	25.8 ± 4.1	15.6 ± 5.0	<0.001
Arms	2.5 ± 0.4	1.3 ± 0.4	<0.001
Legs	7.3 ± 1.1	5.6 ± 1.6	0.020
Trunk	15.0 ± 3.4	7.8 ± 3.2	<0.001
Trunk FM:total FM	0.58 ± 0.19	0.49 ± 0.14	0.003
<i>Fat free mass (%)</i>			
Total	64.8 ± 4.9	75.8 ± 5.8	<0.001
Arms	73.2 ± 5.4	84.0 ± 4.8	<0.001
Legs	65.1 ± 5.0	72.5 ± 5.4	0.005
Trunk	60.4 ± 6.3	74.9 ± 7.9	<0.001
<i>Fat free mass (kg)</i>			
Total	47.5 ± 5.2	48.0 ± 6.7	0.853
Arms	6.9 ± 1.4	7.0 ± 1.0	0.886
Legs	13.7 ± 2.6	14.5 ± 2.5	0.472
Trunk	22.7 ± 1.8	22.5 ± 3.0	0.885

Comparison between groups by independent *t*-test; $P < 0.05$ was considered significant.

Table 2 General characteristics and anthropometric measurements of the non-physically active and physically active spinal cord injury men

	Non-physically active ($n = 8$)	Physically active ($n = 14$)
Age (years)	35 ± 12	29 ± 8
Length (m)	1.72 ± 0.7	1.72 ± 0.6
Duration of injury (years)	14 ± 10	8 ± 7
Body weight (kg)	73.3 ± 4.6	$63.5 \pm 9.4^*$
Body mass index (kgm^{-2})	24.8 ± 3.1	$21.3 \pm 2.4^*$
Time of physical activity practice (months)	–	14.0 ± 10.0
Hours/week of exercise practice	–	13.0 ± 7.0

Comparison between groups by independent *t*-test; $*P < 0.05$.

Table 4 Comparison of glucose homeostasis between non-physically active and physically active groups

	Non-physically active ($n = 8$) (mean $\pm$ SD)	Physically active ($n = 14$) (mean $\pm$ SD)
Fasting plasma glucose (mg/dl)	89.0 ± 9.5	84.3 ± 6.5
Fasting plasma insulin ($\mu\text{U/ml}$)	13.4 ± 5.5	$8.3 \pm 4.4^*$
HOMA-IR	1.7 ± 0.7	$1.1 \pm 0.5^*$

Comparison between groups by independent *t*-test; $*P < 0.05$.

Table 5 Correlation between plasma insulin, glucose and HOMA with FM and FFM considering non-physically active ($n = 8$), physically active ($n = 14$), and all participants ($n = 22$)

	Non-physically active ($n = 8$)		Physically active ($n = 14$)		All ($n = 22$)	
	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
<i>Fasting plasma insulin</i>						
Total FM (%)	0.55	0.139	0.33	0.238	0.59	0.004
Arms (%)	0.21	0.578	0.17	0.562	0.53	0.012
Legs (%)	-0.17	0.662	0.06	0.832	0.29	0.186
Trunk (%)	0.71	0.037	0.34	0.231	0.61	0.003
Trunk FM:total FM (kg)	0.83	0.005	0.37	0.189	0.59	0.004
Total FFM (%)	-0.55	0.139	-0.03	0.238	-0.59	0.004
Arms (%)	-0.22	0.578	-0.12	0.182	-0.51	0.016
Legs (%)	0.17	0.662	0.01	0.964	-0.27	0.228
Trunk (%)	-0.71	0.037	-0.37	0.184	-0.62	0.002
<i>Fasting plasma glucose</i>						
Total FM (%)	0.36	0.353	-0.22	0.435	0.09	0.694
Arms (%)	0.10	0.794	-0.50	0.064	-0.08	0.713
Legs (%)	0.53	0.160	-0.49	0.069	-0.06	0.797
Trunk (%)	0.13	0.705	-0.28	0.324	0.03	0.912
Trunk FM:total FM (kg)	0.36	0.353	-0.06	0.820	0.15	0.504
Total FFM (%)	-0.359	0.353	0.22	0.435	-0.09	0.694
Arms (%)	-0.168	0.662	0.53	0.049	0.08	0.705
Legs (%)	-0.527	0.160	0.49	0.075	0.05	0.801
Trunk (%)	-0.132	0.705	0.25	0.373	-0.04	0.872
<i>HOMA</i>						
Total FM (%)	0.51	0.182	0.38	0.178	0.58	0.004
Arms (%)	0.15	0.705	0.23	0.416	0.51	0.015
Legs (%)	-0.24	0.537	0.12	0.659	0.28	0.204
Trunk (%)	0.69	0.047	0.35	0.212	0.59	0.004
Trunk FM:total FM (kg)	0.79	0.015	0.33	0.238	0.57	0.006
Total FFM (%)	-0.51	0.182	-0.38	0.178	-0.58	0.004
Arms (%)	-0.16	0.662	-0.18	0.532	-0.49	0.020
Legs (%)	0.24	0.537	-0.05	0.844	-0.25	0.251
Trunk (%)	-0.69	0.047	-0.38	0.173	-0.59	0.003

P and *r* values obtained by the Spearman correlation.

0.004, respectively) and with the trunk FM:t-FM (kg) ratio ($r = 0.59$, $P = 0.004$; $r = 0.57$, $P = 0.006$, respectively). However, FPI and HOMA were negatively associated with total FFM ($r = -0.59$, $P = 0.004$; $r = -0.58$, $P = 0.004$, respectively), r-FFM (arms, $r = -0.51$, $P = 0.016$; $r = -0.49$, $P = 0.020$, respectively; trunk: $r = -0.62$, $P = 0.002$; $r = -0.59$, $P = 0.003$, respectively) and with the legs FM: t-FM (kg) ratio ($r = -0.57$, $P = 0.005$; $r = -0.55$, $P = 0.008$, respectively).

In the PA group the correlations were not statistically significant, while in the N-PA group the FPI levels and HOMA-IR were positively associated with trunk FM and with the trunk FM:t-FM (kg) ratio. Consequently, these parameters were negatively associated with the legs FM:t-FM (kg) ratio. No measures of fat distribution were related to FPG in either group (Table 5).

Discussion

To our knowledge, there are no studies evaluating the regional fat distribution in PA c-SCI individuals

matched by age, sex, and level of injury. In this study, the primary finding is the lower total and regional FM in PA individuals with c-SCI compared to the N-PA group.

The use of DXA in this study was essential for obtaining regional data of body composition in individuals with c-SCI. This method can effectively assess segmental body composition based on the entire body measurement and has been suggested to be the most appropriate method of measuring the body composition of individuals with SCI.²⁰

Fat depots from different sites of the body exhibit particular functionality and structural characteristics that lead to pathology.²¹ Individuals with SCI have increased risk for metabolic disorders compared to the general population including impaired glucose tolerance and insulin resistance.^{22,23} Therefore, for prevention of these metabolic disorders, an important question in people with SCI is whether an increase in adipose tissue or loss of muscle tissue is the major contributor to these metabolic disease risks. Some studies have shown the impact of physical activity on the relation

between adipose tissue and risk for insulin resistance in the SCI population.^{15,17,20,23,24}

In a previous study we showed that time of physical exercise practice after injury in men with c-SCI is related to lower body fat.¹⁷ This study reinforces this finding and shown that the FM in all regions of the body was also lower in the PA group, indicating that the exercise practiced at least three times a week for at least 3 months was sufficient to promote positive changes in fat distribution in individuals with c-SCI by mechanisms not yet clearly identified. Furthermore, the highest percentage of difference between the two groups is concentrated on the trunk FM.

The absolute fat free mass was similar between the groups, but in percentage was higher in physically active men, which had almost 10 kg less total body weight than the non-active. These findings suggest that the physical exercise practiced by these individuals preserving fat free mass. Besides, the exercise was able to mobilize the total FM and ameliorate FM distribution, with lower trunk FM:t-FM ratio for the PA group.

Some studies showed that spinal cord injury, in non-physically active individuals, is associated with increased body FM, mainly in the lower extremities⁴. The regional adiposity was previously investigated in sedentary SCI individuals and young athletes.²⁰ Our findings in the PA group are in agreement with the study conducted by Mojtahedi *et al.*²⁰ which evaluated regional body composition in athletes with spinal cord injury and also found lower total and trunk FM compared to sedentary controls. We compared our data on trunk FM (15 kg) in the N-PA group with that reported by Gorgey and Gater²³ in individuals with paraplegia (12 kg). The higher amount of trunk FM observed in individuals in this study may be attributed to the fact of their having tetraplegia, which is associated with increased fat deposition in the trunk.^{4,25} Physical activity may provide adaptations to regulate lipolysis in individuals with c-SCI; however, the mechanisms have not been described in the literature.

Impaired glucose tolerance and insulin resistance are important metabolic disorders and the most prevalent in the individuals with c-SCI.^{9,23,24} In this study, we showed that the PA group had lower FPI levels and HOMA compared to the N-PA group. However, most of the associations between fat distribution and insulin resistance were observed when all participants were considered. Both FPI and HOMA were positively associated with t-FM, r-FM, and trunk FM:t-FM ratio. These data suggest that the fat deposition in the trunk of the N-PA group seems to be the main factor associated with insulin resistance. The lack of associations in

the PA group may be partly explained by the relatively low adiposity, since, when compared with highly active athletes with SCI our group had the same or lower values of total FM (% and kg) and trunk FM. Besides, it is probable that inter muscular adipose tissue may be higher in the PA group.²⁰

In conclusion, physical exercise is associated with lower t-FM, r-FM, and insulin resistance, which could contribute to the decrease of the risk of cardiovascular and metabolic conditions in individuals with c-SCI.

References

- 1 National Spinal Cord Injury Statistical Center. Spinal cord injury facts & figures at a glance [document on the Internet]. 2012 [updated 2012 February]. Available from: https://www.nscisc.uab.edu/PublicDocuments/fact_figures_docs/Facts%202012%20Feb%20Final.pdf.
- 2 Jackson AB, Dijkers M, Devivo MJ, Poczekatek RB. A demographic profile of new traumatic spinal cord injuries: change and stability over 30 years. *Arch Phys Med Rehabil* 2004;85(11):1740–8.
- 3 Jones LM, Goulding A, Gerrard DF. DEXA: a practical and accurate tool to demonstrate total and regional bone loss, lean tissue loss and fat mass gain in paraplegia. *Spinal Cord* 1998;36(9):637–40.
- 4 Spungen AM, Adkins RH, Stewart CA, Wang J, Pierson RN Jr, Waters RL, Bauman WA. Factors influencing body composition in persons with spinal cord injury: a cross-sectional study. *J Appl Physiol* 2003;95(6):2398–407.
- 5 Normell LA. Distribution of impaired cutaneous vasomotor and sudomotor function in paraplegic man. *Scand J Clin Lab Invest Suppl* 1974;138:25–41.
- 6 Maruyama Y, Mizuguchi M, Yaginuma T, Kusaka M, Yoshida H, Yokoyama K, *et al.* Serum leptin, abdominal obesity and the metabolic syndrome in individuals with chronic spinal cord injury. *Spinal Cord* 2008;46(7):494–9.
- 7 Smith SR, Lovejoy JC, Greenway F, Ryan D, de Jonge L, de la Bretonne J, Volafava J, Bray GA. Contributions of total body fat, abdominal subcutaneous adipose tissue compartments, and visceral adipose tissue to the metabolic complications of obesity. *Metabolism* 2001;50(4):425–35.
- 8 Lavie CJ, Milani RV, Ventura HO. Obesity and cardiovascular disease: risk factor, paradox, and impact of weight loss. *J Am Coll Cardiol* 2009;53(21):1925–32.
- 9 Gorgey AS, Mather KJ, Gater DR. Central adiposity associations to carbohydrate and lipid metabolism in individuals with complete motor spinal cord injury. *Metabolism* 2011;60(6):843–51.
- 10 Cefalu WT, Wang ZQ, Werbel S, Bell-Farrow A, Crouse JR 3rd, Hinson WH, Terry JG, Anderson R. Contribution of visceral fat mass to the insulin resistance of aging. *Metabolism* 1995;44(7):954–9.
- 11 Boyko EJ, Fujimoto WY, Leonetti DL, Newell-Morris L. Visceral adiposity and risk of type 2 diabetes: a prospective study among Japanese Americans. *Diabetes Care* 2000;23(4):465–71.
- 12 Després JP. Cardiovascular disease under the influence of excess visceral fat. *Crit Pathw Cardiol* 2007;6(2):51–9.
- 13 Edwards LA, Bugaresti JM, Buchholz AC. Visceral adipose tissue and the ratio of visceral to subcutaneous adipose tissue are greater in adults with than in those without spinal cord injury, despite matching waist circumferences. *Am J Clin Nutr* 2008;87(3):600–7.
- 14 American College of Sports Medicine, Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, Salem GJ, Skinner JS. American College of Sports Medicine position stand. Exercise and physical activity for older adults. *Med Sci Sports Exerc* 2009;41(7):1510–30.
- 15 Hjeltnes N, Galuska D, Björnholm M, Aksnes AK, Lannem A, Zierath JR, Wallberg-Henriksson H. Exercise-induced overexpression of key regulatory proteins involved in glucose uptake and metabolism in tetraplegic persons: molecular mechanism for improved glucose homeostasis. *FASEB J* 1998;12(15):1701–12.

- 16 Mohr T, Dela F, Handberg A, Biering-Sørensen F, Galbo H, Kjaer M. Insulin action and long term-electrically induced training in individuals with spinal cord injuries. *Med Sci Sports Exerc* 2001; 33(8):1247–52.
- 17 Koury JC, Passos MC, Figueiredo FA, Chain A, Franco JG. Time of physical exercise practice after injury in cervical spinal cord-injured men is related to the increase in insulin sensitivity. *Spinal Cord* 2013;51(2):116–9.
- 18 Capaul M, Zollinger H, Satz N, Dietz V, Lehmann D, Schurch B. Analyses of 94 consecutive spinal cord injury patients using ASIA definition and modified Frankel score classification. *Paraplegia* 1994;32(9):583–7.
- 19 HOMA Calculator. The Oxford Center for Diabetes. Endocrinology & Metabolism, Diabetes Trial Unit. Available from: <http://www.dtu.ox.ac.uk> [Accessed 2011 December 20].
- 20 Mojtabedi MC, Valentine RJ, Arngrímsson SA, Wilund KR, Evans EM. The association between regional body composition and metabolic outcomes in athletes with spinal cord injury. *Spinal Cord* 2008;46(3):192–7.
- 21 Wronska A, Kmiec Z. Structural and biochemical characteristics of various white adipose tissue depots. *Acta Physiol (Oxf)* 2012; 205(2):194–208.
- 22 Bauman WA, Spungen AM. Carbohydrate and lipid metabolism in chronic spinal cord injury. *J Spinal Cord Med* 2001;24(4):266–77.
- 23 Gorgey AS, Gater DR. A preliminary report on the effects of the level of spinal cord injury on the association between central adiposity and metabolic profile. *PM R* 2011;3(5):440–6.
- 24 LaVela SL, Evans CT, Prohaska TR, Miskevics S, Ganesh SP, Weaver FM. Males aging with a spinal cord injury: prevalence of cardiovascular and metabolic conditions. *Arch Phys Med Rehabil* 2012;93(1):90–5.
- 25 Spungen AM, Bauman WA, Wang J, Pierson RN Jr. Measurements of body fat in individuals with tetraplegia: a comparison of eight clinical methods. *Paraplegia* 1995;33(7):402–8.