Acta Med. Okayama, 2006
Vol. 60, No. 2, pp. 99-106

Acta Medica Okayama
http://www.lib.okayama-u.ac.jp/www/acta/

Original Article

Assessment of Total and Segmental Body Composition in Spinal Cord-Injured Athletes in Okayama Prefecture of Japan

Yoshihide Inukai[a], Kayo Takahashi[b], Da-Hong Wang[a]*, and Shohei Kira[a]

[a]*Department of Public Health, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama 700-8558, Japan, and*
[b]*Faculty of Education, Okayama University, Okayama 700-8530, Japan*

This study assessed total and segmental distribution of fat mass (FM) in athletes with spinal cord injury (SCI) and examined the relationships between segmental distribution of fat mass and age, injury level, athletic history, and training load in order to provide useful information for improvements in their physical strength and training. Twenty-five male athletes with SCI participated in the study. The whole bone composition was measured by a dual-energy X-ray absorptiometry (DXA) method for the calculation of bone minerals, FM, and fat-free mass. The percent fat of the trunk, arms, and legs was also calculated. The percent fat in the legs was highest in comparison with that in the trunk and arms ($p < 0.001$), and the percent fat in the trunk was higher than that in the arms ($p < 0.001$). The body fat ($p < 0.01$), waist circumference ($p < 0.01$), and waist-to-hip ratio ($p < 0.0001$) were higher in the group aged 40 or older in comparison with that aged 39 or younger. Path analysis revealed that training load was a factor decreasing the percent fat on the arms and trunk ($p < 0.01$), and athletic history was a factor reducing the percent fat on the arms ($p < 0.05$). Our study suggests that exercise is effective in reducing the waist circumference, waist-to-hip ratio, and percent body fat of SCI individuals, and that such effects can help to enhance athletic performance and likely to protect against development of metabolic syndromes resulting from a sedentary lifestyle.

Key words: body composition, percentage of fat, DXA, spinal cord-injured athletes, path analysis

Enhancing the athletic performance of athletes is always a challenge in the area of sports medicine research. Assessment of the body composition of athletes is important to achieving real improvements in physical strength and training quality. For athletes with spinal cord injury (SCI), reduced physical capacity in injured parts of the body would result in great alterations in their body composition. Assessment of their body composition turns out to be an important way of measuring the results of an athlete's training, since more SCI athletes are pursuing higher goals for the establishment of great records. In addition, the prevalence of obesity, cardiovascular disease, *etc.* is reported to be higher in the SCI population [1], therefore, assessment of the body composition of SCI athletes can also help to promote good health by protecting against the development of obesity and other lifestyle-related diseases.

Received September 1, 2005; accepted October 12, 2005.
*Corresponding author. Phone: +81-86-235-7184; Fax: +81-86-226-0715
E-mail: dahong@md.okayama-u.ac.jp (DH. Wang)

In Okayama Prefecture, few physically disabled people engage in sports, and data regarding the body characteristics and composition of disabled athletes are insufficient. Therefore, study of the body characteristics and composition of SCI athletes should contribute to a deeper understanding of sports/physical activity by disabled people in Okayama Prefecture and further to the preservation of their health. Many studies have shown that in the case of athletes with SCI, their body composition, which includes muscle, bone mineral, and fat content, is considered to be significantly influenced by disabilities [1-3]. Bauman [1], Uebelhart [2], and Wilmet [3] have demonstrated a reduction in the fat-free mass (FFM) and an increase in the fat mass (FM) in athletes after spinal cord injury. Olle *et al.* [4] have reported that the percent fat values in physically active paraplegics are significantly lower than those in sedentary paraplegics, but are still higher than those in able-bodied individuals according to results obtained by the impedance method. Lussier *et al.* [5] have found that the percent fat in elite female paraplegic athletes is greater than that in able-bodied individuals in the same age group. However, most studies of the body composition of athletes with SCI have focused primarily on the percentage of FM and lean body mass (LBM) of the whole body, and few have investigated the regional body composition. We believe that an assessment of body composition, not only the total body FM but also the segmental distribution of FM such as in the trunk, arms, and legs, is important to promoting the health of SCI athletes and enhancing their athletic ability.

In the present study, we investigated the segmental distribution of FM by the dual-energy X-ray absorptiometry (DXA) method and examined differences in segmental distribution of FM by age, injury level, athletic history, and training load in order to provide useful information for promoting the health of athletes with SCI.

Subjects and Methods

Subjects. Twenty-five male athletes with SCI participated in this study. The subjects were fully informed in advance regarding the objectives of the study, the study methods involved no risks, and written informed consent was obtained from each subject for participation in this study.

Measurement methods. The height, body weight, circumferences of the chest, waist and hip, circumferences of the right and left shoulders, circumferences of the right and left arms and forearms, and lengths of the right and left arms were measured by anthropometric standard procedures. Using the DXA method, the total bone composition was measured to calculate the bone mineral, FM, and FFM, and these data were used to calculate the percent fat. Moreover, the body was divided into 4 parts, namely, the head, trunk, arms, and legs, and the percent body fat was individually calculated for the trunk, arms, and legs.

The subjects were instructed to refrain from eating and drinking 2 h before the measurement, and the measurement was carried out after taking off all metal products on the body. Subjects were then asked to lie on their backs on a bed, and the forearms were fixed at the maximal pronated position. Hologis QDR4500 A software version 9.10 D was used for the measurements.

Statistical analysis. All data are expressed as the means ± standard deviation. The Student's *t*-test was used to analyze the differences between the 2 groups, and the analysis of variance (ANOVA) was used to analyze differences among the 3 groups followed by multiple comparison if necessary. In addition, we performed path analysis using the percent fat of each segment as dependent variables, and the age, site of injury, period since injury, athletic history, and training load as independent variables (Fig. 1). SPSS11.0J and Amos 5.0 for Windows were used for path analysis.

Results

Backgrounds and anthropometric characteristics of the subjects. Table 1 shows that the mean age was 35.6 ± 9.7 years, the mean period since injury was 15.7 ± 8.8 years, and the mean age at the time of injury was 20.0 ± 8.7 years. All subjects regularly participated in some kind of athletic training, including basketball (n = 12), track and field (n = 5), and tennis (n = 8) with wheelchairs. The mean period of their athletic careers was 9.8 ± 6.9 years, the mean number of training days was 3.2 ± 1.5 days per week, and the mean number

Table 1 Backgrounds and anthropometric characteristics of the subjects[a]

		Wheelchair basketball athletes (N=12)	Wheelchair track & field athletes (N=5)	Wheelchair tennis athletes (N=8)	All subjects (N=25)
Age (yr)		32.3 ± 7.6	37.6 ± 8.0	39.5 ± 11.5	35.6 ± 9.7
Years after injury		15.0 ± 8.7	13.0 ± 4.2	18.6 ± 10.2	15.7 ± 8.8
Anthropometry	Whole body fat (%)	24.7 ± 4.6	20.9 ± 4.4	27.3 ± 7.4	25.5 ± 6.4
	Height (cm)	169.6 ± 5.4	172.8 ± 5.2	167.9 ± 5.4	169.7 ± 5.7
	Body weight (Kg)	66.5 ± 11.7	69.0 ± 10.3	66.1 ± 13.5	66.9 ± 12.1
	BMI[b]	23.1 ± 3.7	23.0 ± 2.8	23.6 ± 5.3	23.2 ± 4.1
	Chest circumference (cm)	100.3 ± 11.8	100.9 ± 7.4	98.8 ± 17.0	99.9 ± 11.8
	Waist circumference (cm)	81.4 ± 6.9	79.4 ± 5.1	82.3 ± 7.1	81.7 ± 6.4
	Hip circumference (cm)	92.1 ± 5.1	91.4 ± 4.2	92.6 ± 5.8	92.1 ± 4.6
	Waist-to-hip ratio	0.88 ± 0.1	0.87 ± 0.2	0.89 ± 0.1	0.88 ± 0.2
	Right shoulder circumference (cm)	45.5 ± 4.8	45.5 ± 2.5	45.5 ± 3.5	45.5 ± 4.0
	Left shoulder circumference (cm)	44.4 ± 4.0	45.1 ± 3.4	44.5 ± 6.1	44.6 ± 4.7
	Right upper arm circumference (cm)	32.2 ± 4.8	32.3 ± 2.5	32.4 ± 3.5	32.7 ± 3.4
	Left upper arm circumference (cm)	32.7 ± 2.7	32.0 ± 2.1	32.8 ± 3.8	32.6 ± 3.0
	Right forearm circumference (cm)	28.0 ± 1.8	28.8 ± 1.0	27.8 ± 2.5	28.1 ± 2.0
	Left forearm circumference (cm)	26.9 ± 1.4	28.2 ± 1.1	27.1 ± 2.0	27.2 ± 1.6
	Right arm length (cm)	72.7 ± 3.7	77.5 ± 1.8 *	70.7 ± 4.0 §	73.0 ± 4.3
	Left arm length (cm)	73.1 ± 2.9	77.2 ± 2.5 *	71.4 ± 4.8 §	73.4 ± 4.1
Sports/Exercise	Sports experience (yr)	9.9 ± 6.6	7.7 ± 5.5	10.9 ± 7.7	9.8 ± 6.9
	Exercise frequency per week (d)	2.6 ± 1.2	4.8 ± 1.3 *	3.0 ± 1.2 §	3.2 ± 1.5
	Exercise duration per week (h)	7.8 ± 4.0	14.4 ± 5.7 *	8.9 ± 4.3 §	9.7 ± 6.9

[a]The values are expressed as means ± SD. The symbol * indicates significant differences (p<0.05) between the wheelchair basketball athletes and the wheelchair track and field athletes. The symbol § indicates significant differences (p<0.05) between the wheelchair track and field athletes and the weelchair tennis athlets. The differnces among groups were analyzed by ANOVA.
[b]body mass index.

of training hours per week was 9.7 ± 6.9 hours.

Percent body fat. Table 1 summarizes the physical characteristics of the SCI athletes by the type of sport practiced. There were no significant differences in physical parameters among the types of sports that the athletes participated in, except in the lengths of the right or left arms.

Table 2 shows that the percent body fat of the subjects was 25.5 ± 6.4% for the whole body, 23.0 ± 7.9% for the trunk, 19.8 ± 7.2% for the right arm, 20.7 ± 7.5% for the left arm, 35.3 ± 7.6% for the right leg, and 35.2 ± 7.7% for the left leg. The percent fat in the trunk was significantly higher than that in the arms (Right: p = 0.0370; Left: p = 0.0440), and the percent fat in the legs was significantly higher than those in the trunk and arms (p = 0.0001).

Table 2 Percent fat in SCI athletes

Segment	Body fat (%)
Whole body	25.5 ± 6.4
Trunk	23.0 ± 7.9
Right arm	19.8 ± 7.2[a]
Left arm	20.7 ± 7.5[a]
Right leg	35.3 ± 7.6[b]
Left leg	35.2 ± 7.7[b]

Data are expressed as mean ± SD.
[a] vs. trunk (p < 0.05)
[b] vs. trunk, right arm, left arm (p < 0.0001)

Percent fat by the age. When the group of the athletes aged 40 years or older (n = 8) was compared with the group of the athletes aged 39 years or younger (n = 17), there were significant differences in the percent fat of the whole body (28.6 ± 6.1 vs. 23.0 ± 4.3%, respectively: p = 0.0090), the trunk (27.3 ± 7.7% vs. 19.7 ± 5.2%, respectively: p = 0.0060), the right arm (22.1 ± 6.1% vs. 17.1 ± 4.9%, respectively: p=0.0130), and the left arm (23.3 ± 5.9 % vs. 17.9 ± 5.3%, respectively: p = 0.0170). Nevertheless, no significant differences were observed in the legs (Table 3). However, BMI showed no difference between subjects aged 40 years

Table 3 Comparison of body composition by the age in SCI athletes

	20–39 years	40–55 years
BMI	23.1 ± 3.5	23.9 ± 2.9
Waist circumference (cm)	77.6 ± 3.4	84.1 ± 6.0**
Waist-to-hip ratio	0.85 ± 0.03	0.92 ± 0.06***
Whole body fat (%)	23.0 ± 4.3	28.6 ± 6.1**
Fat in trunk (%)	19.7 ± 5.2	27.3 ± 7.7**
Fat in right arm (%)	17.1 ± 4.9	22.1 ± 6.1*
Fat in left arm (%)	17.9 ± 5.9	23.3 ± 5.9*
Fat in right leg (%)	34.6 ± 7.3	38.8 ± 6.0
Fat in left leg (%)	34.3 ± 7.1	37.0 ± 7.5

Data are expressed as mean ± SD. *$p < 0.05$, **$p < 0.01$, ***$p < 0.0001$.

or older (23.9 ± 2.9) and subjects aged 39 years or younger (23.1 ± 3.5) ($p = 0.1150$).

Percent fat by the level of spinal cord injury. The subjects were divided into 2 groups according to the segment of injury: the high paraplegia (HP) group (n = 11) with lesions at T-7 or higher, the low paraplegia (LP) group (n = 14) with lesions at T-8 or lower. Regarding the level of spinal cord injury, the percent fat of the whole body was 27.4 ± 6.3% for the HP group with injury at T-7 or higher, and 25.4 ± 4.3% for the LP group. Moreover, a higher percent fat was observed in the trunk and arms of the HP group. In particular, the percent fat in the trunk was significantly higher by 4.3 % in the HP group ($p = 0.0414$) (Table 4).

Percent fat by the period since spinal cord injury/athletic training. When the group with 15 years or more since the time of injury (n = 11) was compared with the group with less than 15 years since injury (n = 14), it was found that the percent body fat was higher in the former group at all segments, and there were significant differences in the whole body (27.6 ± 6.1% vs. 22.5 ± 4.3%, respectively: $p = 0.0120$), the trunk (26.0 ± 8.0% vs. 19.0 ± 4.6%, respectively: $p = 0.0070$), the right arm (22.8 ± 5.4% vs. 15.7 ± 4.5%, respectively: $p = 0.0010$), and the left arm (23.3 ± 5.6% vs. 16.6 ± 4.8 %, respectively: $p = 0.0020$). However, there were no differences in the percent fat of the legs according to the period since injury (Table 5). Furthermore, there were no significant differences in all measured segments between the group with an athletic history of 9 years or longer (n = 14) and the group with an athletic history shorter than 9 years (n = 11).

Percent fat by the training load per week. Table 6 shows that the training load per week greatly influenced the fat percentage in each segment. In the group of athletes who trained for 7 h or more per week (n = 12), the percent fat of the whole body, trunk, right arm, left arm, right leg, and left leg were 21.8 ± 2.8%, 18.0 ± 3.6%, 15.4 ± 3.5%, 15.8 ± 3.7%, 33.5 ± 6.6%, and 34.0 ± 6.9%, respectively. In contrast, in the group of athletes who trained less than 7 h per week (n = 13), the percent fat of the whole body, trunk, right arm, left arm, right leg, and left leg were 27.9 ± 6.3 %, 26.4 ± 7.5%, 22.5 ± 6.0%, 23.5 ± 5.7%, 36.2 ± 7.5%, and 36.0 ± 7.4%, respectively. Although there were no differences between the 2 groups in terms of age (36.7 ± 10.6 years vs. 34.5 ± 9.3 years: $p = 0.3020$) and period since injury (18.3 ± 10.1year vs. 13.3 ± 7.1: $p = 0.091$), there were significant differences in the percent fat of the whole body ($p = 0.0030$), trunk ($p = 0.0010$), and both arms (Right arm, $p = 0.0010$; Left arm, $p =$

Table 4 Comparison of body composition by the level of spinal cord injury

	High paraplegia	Low paraplegia
BMI	22.9 ± 2.4	22.6 ± 4.0
Waist circumference (cm)	80.2 ± 5.9	79.5 ± 5.0
Waist-to-hip ratio	0.88 ± 0.06	0.87 ± 0.05
Whole body fat (%)	27.4 ± 6.3	25.4 ± 4.3
Fat in trunk (%)	26.4 ± 6.4	22.1 ± 5.5*
Fat in right arm (%)	20.1 ± 9.5	19.5 ± 5.1
Fat in left arm (%)	21.0 ± 9.5	20.4 ± 5.1
Fat in right leg (%)	36.5 ± 7.5	33.5 ± 9.5
Fat in left leg (%)	36.0 ± 5.4	33.9 ± 9.0

Data are expressed as mean ± SD. *$p < 0.05$.

Table 5 Comparison of body composition by the period since spinal cord injury in SCI athletes

	Less than 15 years	More than 15 years
BMI	21.9 ± 3.7	23.7 ± 2.8
Waist circumference (cm)	77.8 ± 4.3	82.2 ± 5.6*
Waist-to-hip ratio	0.85 ± 0.05	0.89 ± 0.05*
Whole body fat (%)	22.5 ± 4.3	27.6 ± 6.1*
Fat in trunk (%)	19.0 ± 4.6	26.0 ± 8.0**
Fat in right arm (%)	15.7 ± 4.5	22.8 ± 5.4**
Fat in left arm (%)	16.6 ± 4.8	23.3 ± 5.6**
Fat in right leg (%)	34.7 ± 8.1	36.0 ± 7.6
Fat in left leg (%)	34.8 ± 7.9	35.6 ± 8.0

Data are expressed as mean ± SD. $^{*}p < 0.05$, $^{**}p < 0.01$.

Table 6 Comparison of body composition by the total exercise duration per week in SCI athletes

	Less than 7 hours	7 hours or more
Age (yr)	36.7 ± 10.6	34.5 ± 9.3
Period of injury (yr)	18.3 ± 10.1	13.3 ± 7.1
BMI	24.3 ± 3.4	21.2 ± 2.7**
Waist circumference (cm)	84.8 ± 5.9	77.9 ± 4.4**
Waist-to-hip ratio	0.91 ± 0.06	0.84 ± 0.05**
Whole body fat (%)	27.9 ± 6.3	21.8 ± 2.8**
Fat in trunk (%)	26.4 ± 7.5	18.0 ± 3.6**
Fat in right arm (%)	22.5 ± 6.0	15.4 ± 3.5**
Fat in left arm (%)	23.5 ± 5.7	15.8 ± 3.7***
Fat in right leg	36.2 ± 7.5	33.5 ± 6.6
Fat in left leg	36.0 ± 7.4	34.0 ± 6.9

Data are expressed as mean ± SD. $^{**}p < 0.01$, $^{***}p < 0.001$.

0.0001).

Factors influencing the fat percentage of each segment. Path analysis (Fig. 1) suggested that age was a factor increasing the percent fat of each segment, and the effects of age on the percent fat were significantly higher, with path coefficients of 0.68 (p = 0.0001), 0.69 (p = 0.0001), 0.68 (p = 0.0001), and 0.56 (p = 0.0070) for the right arm, left arm, trunk, and right leg, respectively. As the ages of the subjects increased by one year, the percent fat of each segment increased by 0.43%, 0.44%, 0.52%, and 0.41% in the right arm, left arm, trunk, and right leg, respectively. The training load and the athletic history were demonstrated to be factors that reduce the percent fat of the arms and trunk, however, their effects on the legs were not found to be significant. The training load negatively related to the percent fat of each segment, being −0.50 (p = 0.0030), −0.54 (p = 0.0001), and −0.46 (p = 0.0040) for the right arm, left arm, and trunk, respectively. When the weekly training load increased by 1 h, the percent fat of the right arm, left arm, and trunk decreased by 0.58%, 0.64%, and 0.65%, respectively. The athletic history was found to have a negative relation to the percent fat of the arms, being −0.52 (p = 0.0310) and −0.55 (p = 0.0100) for the right arm and left arm, respectively. When the athletic history extended by 1 year, the percent fat of the right arm and left arm decreased by 0.46% and 0.50%, respectively.

The percent fat of the arms and trunk was significantly higher in the group with more than 15 years since the time of injury than in that with less than 15 years since injury (Table 5); however, path analysis demonstrated that the period of injury was not a factor that significantly affected body fat (Fig. 1).

Discussion

In the present study, we employed the DXA

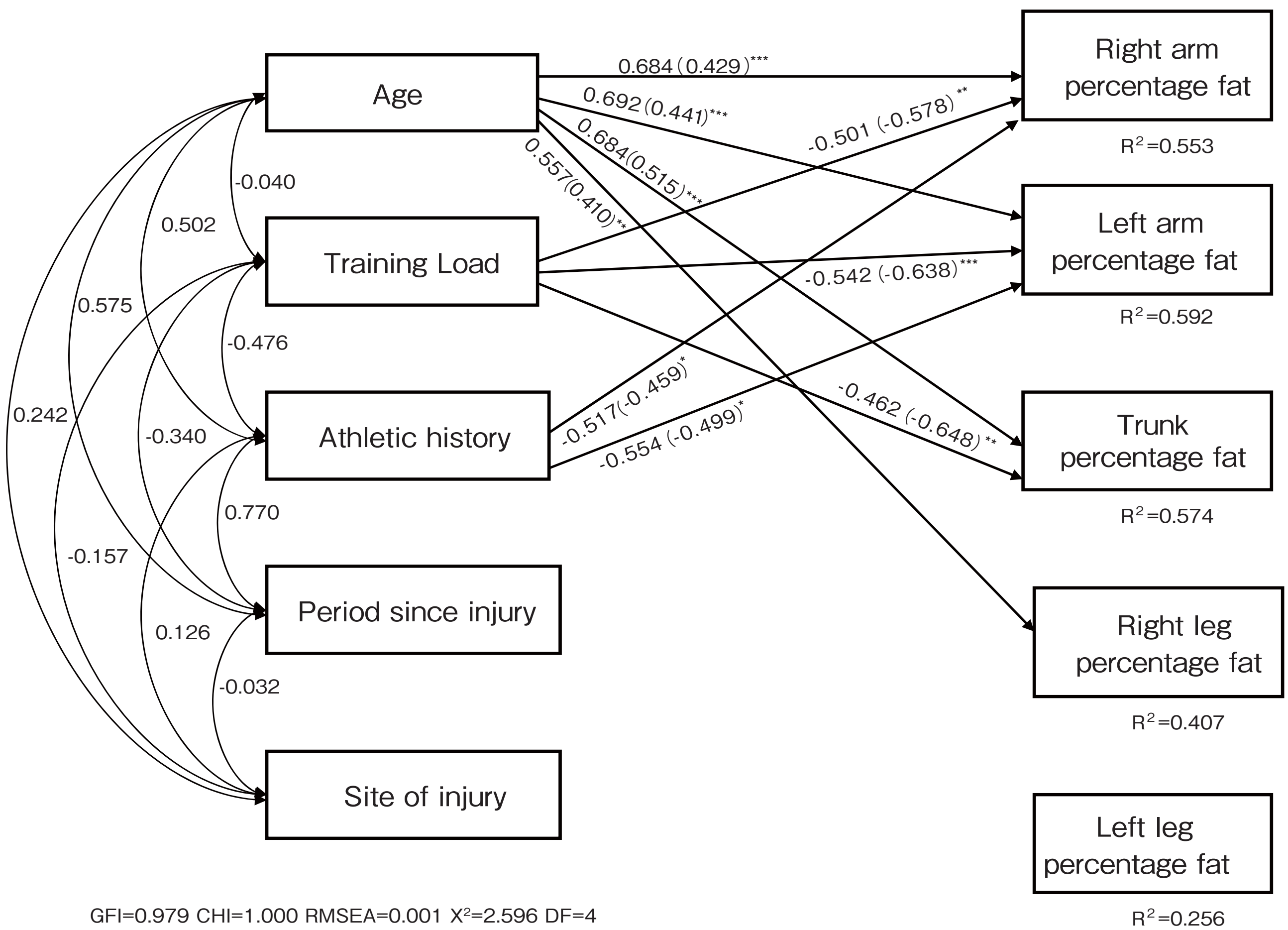

Fig. 1 Causal relationship between explanatory variables and percent fat in each segment of SCI athletes. The cause-effect structural model is expressed by the path diagram, and the path coefficients that indicate the degrees of influence are designated by arrows (*p < 0.05, **p < 0.01, ***p < 0.001). The values on the arrows indicate the path coefficients of standardized solution, and the values within the parentheses indicate the path coefficients of non-standardized solution.

method to measure the body composition of SCI subjects, as this method can effectively assess segmental body composition based on the entire body measurement and has been suggested to be the most reasonable method of measuring the body composition of SCI individuals [6] in comparison with other simplified methods such as the total body water (TBW) [7], total body potassium (TBK) [8], bioelectrical impedance analysis (BIA) [9], and skinfold thickness measurement [5]. The present findings that the fat percentages in both right and left legs were significantly higher than those in the trunk, right, and left arms are considered as a result of that disuse atrophy of the paralyzed body regions due to SCI is possibly responsible for the differences between the fat percentage of the legs and that of the other body regions. Recently, Maggioni *et al.* [10] have also reported a high value of percentage FM in the lower limbs of SCI patients. Accordingly, in measurements of the body composition of SCI populations, assessment of their segmental body composition is essential since their body fat distribution is greatly influenced by the level of the injured segment, and assessment of the segmental body composition for athletes with SCI will be helpful to better understanding their health conditions as well as examining the effects of various rehabilitative techniques on different body regions for enhancement of their athletic ability.

In comparison with the group aged 39 or younger, the percent fat of the whole body and trunk was significantly higher in the group aged 40 or older, increased by 5% and 7%, respectively, and the waist circumference and waist-to-hip ratio were also significantly higher in the group aged 40 or older. Miyatake *et al.* [11] have found that the waist circumference and waist-to-hip ratio are strongly correlated with the visceral fat. A review article has recently recommended that the accuracy and reliability of waist circumference as a substitute measure of visceral adipose tissue for long-standing paraplegia and tetraplegia and indicated waist circumference can be used as an indicator of coronary heart disease risk in these patients [12]. Increased abdominal visceral fat has also been considered to be a risk factor for metabolic syndromes such as hypertension and type 2 diabetes [13–15]. In the SCI population, higher levels of plasma glucose, triglyceride and LDL-cholesterol, and lower levels of HDL-cholesterol were reported [12]. However, regular physical exercise can be expected to help SCI persons improve their body composition and to prevent the development of consequent chronic diseases [16]. In the group with high paraplegia, we found a significantly higher percent fat in the trunk, and a trend of high percent fat in the whole body and arms compared with the low paraplegia group. This result is consistent with the report of Rasmann *et al.* [17], suggesting that paraplegic individuals with injury at higher levels tend to have a higher percent of body fat.

The percent fat of whole body in SCI athletes of our study was approximately 5% lower than in the paraplegic individuals reported by Jones *et al.* [18], although we both employed the DXA technique. This discrepancy was possibly attributed to the fact that the mean body mass index (BMI) of the present subjects was 23.2, whereas it was 24.8 in the study of Jones *et al.*, indicating that the present subjects who engage in sports approximately 10 h per week were less obese. We also found that the percent fat of the trunk in the subjects who exercised for 7 h or more per week was lower by 8.4% than in those who exercised less than 7 h per week, revealing that exercise is effective in reducing the percent body fat that would be expected to protect against the development of chronic diseases resulting from a sedentary lifestyle.

Regarding the percent body fat in individuals who perform exercise, the DXA methods used in our study showed a higher mean percent body fat (25.5%) than other methods. Olle *et al.* [4] have found the percent body fat of physically active subjects to be 15.6%, whereas that of the sedentary subjects was 23.2% by the BIA method. Ide *et al.* [19] have reported the mean percent body fat of wheelchair marathon race competitors to be 16.7–18.7% by the skinfold method. In addition, Bulbilian *et al.* [20] have demonstrated the mean body fat of paraplegic male athletes to be 22.4% by hydrodensitometry. We believe that this discrepancy resulted from the possibility that the leg fat percentage was not accurately reflected by the measurement techniques in their studies. Kocina [21] has also pointed out that the prediction equations used for hydrostatic weighing, anthropometry, and BIA methods are simply estimated from the physical density of able-bodied individuals, and therefore could be a source of estimation error if used in the SCI population [21].

Furthermore, the path analysis revealed that the percent body fat was positively influenced by age and negatively influenced by the training load and athletic history, and was not significantly influenced by the years since injury; these results may indicate that age and training load have a greater effect on the alteration of body fat than do the injury period among SCI athletes; therefore, the fat percentage of each segment may increase as the subjects get older, but exercising on a regular basis may prevent these increases or may even reduce the fat percentage.

Spungen *et al.* [22] have reported that the fat percentage in legs is higher among SCI people in comparison with the matched able-bodied control subjects. When we examined the relationship between training period and the segmental body fat, we found that regular exercise plays an important role in reducing the fat percentages of the trunk and arms, but not that of the legs, suggesting the need to develop effective training approaches to reducing the leg fat percentage in addition to training of the trunk and arms for optimizing the physical performance of SCI athletes.

The potential limitations to the present study include the small sample size and the possibility of a selection bias, that is, the unrandomized selection of subjects in our study. Therefore, the present results do not necessarily represent the whole status of SCI athletes in Okayama Prefecture. Furthermore, since there were no control subjects in the present study, our results regarding the role of exercise in reducing fat mass in the upper extremities of SCI people are inconclusive.

In conclusion, our study suggests the importance of assessing segmental body composition of individuals with SCI. In addition, regular exercise is effective for SCI individuals to reduce their waist circumference, waist-to-hip ratio, and body fat (especially upper-body fat), and probably to further promote their health. How to reduce the leg fat percentage for the enhancement of athletic performance will be an important issue in future research.

Acknowledgments. We are grateful to all those who voluntarily participated in this study. We also wish to thank Yuki Yajima and the Okayama Southern Institute of Health, Okayama Prefecture, Japan for their technical cooperation.

References

1. Bauman WA, Spungen AM, Raza M, Rothstein J, Zhang RL, Zhong YG, Tsuruta M, Shahidi R, Pierson RN Jr and Wang J: Coronary artery disease: metabolic risk factors and latent disease in individuals with paraplegia. Mt Sinai J Med (1992) 59: 163–168.
2. Uebelhart D, Demiaux-Domench B, Roth M and Chantraine A: Bone metabolism in spinal cord injured individuals and in others who have prolonged immobilization. A review. Paraplegia (1995) 33: 669–673.
3. Wilmet E, Ismail AA, Heilporn A, Welraeds D and Bergmann P: Longitudinal study of the bone mineral content and of soft tissue composition after spinal cord section. Paraplegia (1995) 33: 674–677.
4. Olle MM, Pivarnik JM, Klish WJ and Morrow JR: Body composition of sedentary and physically active spinal cord injured individuals estimated from total body electrical conductivity. Arch Phys Med Rehabil (1993) 74: 706–710.
5. Lussier L, Knight J, Bell G, Lohman T and Morris AF: Body composition comparison in two elite female wheelchair athletes. Paraplegia (1983) 21: 16–22.
6. Spungen AM, Bauman WA, Wang J and Pierson RN: Measurement of body fat in individuals with tetraplegia: a comparison of eight clinical methods. Paraplegia (1995) 33: 402–408.
7. George CM, Wells CL and Dugan NL: Validity of hydrodensitometry for determination of body composition in spinal injured subjects. Hum Biol (1988) 60: 771–780.
8. Cardus D and McTaggart WG: Body sodium and potassium in men with spinal cord injury. Arch Phys Med Rehabil (1985) 66: 156–159.
9. Cardus D and Mctaggart WG: Electric impedance measurements in quadriplegia. Arch Phys Med Rehabil (1988) 69: 186–187.
10. Maggioni M, Bertoli S, Margonato V, Merati G, Veicsteinas A and Testolin G: Body composition in spinal cord injury subjects. Acta Diabetol (2003) 40: S183–186.
11. Miyatake N, Takenami S and Fujii M: Evaluation of visceral adipose accumulation in Japanese women and establishment of a predictive formula. Acta Diabetol (2004) 41: 113–117.
12. Buchholz AC and Bugaresti JM: A review of body mass index and waist circumference as markers of obesity and coronary heart disease risk in persons with chronic spinal cord injury. Spinal Cord (2005) 43: 513–518.
13. Jones LM, Legge M and Goulding A: Healthy body mass index values often underestimate body fat in men with spinal cord injury. Arch Phys Med Rehabil (2003) 84: 1068–1071.
14. Hayashi T, Boyko EJ, Leonetti DL, McNeely MJ, Newell-Morris L, Kahn SE and Fujimoto WY: Visceral adiposity is an independent predictor of incident hypertension in Japanese Americans. Ann Intern Med (2004) 40: 992–1000.
15. Nicklas BJ, Penninx BW, Ryan AS, Berman DM, Lynch NA and Dennis KE: Visceral adipose tissue cutoffs associated with metabolic risk factors for coronary heart disease in women. Diabetes Care (2003) 26: 1413–1420.
16. Miyatake N, Takahashi K, Wada J, Nishikawa H, Morishita A, Suzuki H, Kunitomi M, Makino H, Kira S and Fujii M: Daily exercise lowers blood pressure and reduces visceral adipose tissue areas in overweight Japanese men. Diabetes Res Clin Pract (2003) 62: 149–157.
17. Rasmann DN, Spurr GB, Barboriak JJ, Rooney CB, el Ghatit AZ and Bongard RD: Body composition of patients with spinal cord injury. Eur J Clin Nutr (1988) 42: 765–773.
18. Jones LM, Goulding A and 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: 637–640.
19. Ide M, Ogata H, Kobayashi M, Tajima F and Hatada K: Anthropometric features of wheelchair marathon race competitors with spinal cord injuries. Paraplegia (1994) 32: 174–179.
20. Bulbulian R, Johnson RE, Gruber JJ and Darabos B: Body composition in paraplegic male athletes. Med Sci Sports Exerc (1987) 19: 195–201.
21. Kocina P: Body composition of spinal cord injured adults. Sports Med (1997) 23: 48–60.
22. Spungen AM Adkins RH, Stewart CA, Wang J, Pierson RN Jr, Waters RL and Bauman WA: Factors influencing body composition in persons with spinal cord injury: a cross-sectional study. J Appl Physiol (2003) 95: 2398–2407.