The development of a preliminary regression equation for estimating the weight of black South African paraplegic males using anthropometric measurements in Tshwane, South Africa

[a] Snyman H, [b] Herselman MG, [b] Labadarios D
[a] Association for Dietetics in South Africa [b] Division of Human Nutrition, Faculty of Health Sciences, Stellenbosch University
Correspondence to: hsnyman2@eim.ae
Keywords: spinal cord injury (SCI); anthropometric measurements; weight; regression equation; paraplegic persons

Abstract

Objective: To develop a regression equation to estimate the weight of black male paraplegic South African subjects.

Design: Cross-sectional study.

Setting: Outpatient paraplegic clinic of Kalafong Hospital, Tshwane, South Africa.

Subjects: Subjects (n = 43) were selected from a population of black paraplegic males attending the clinic.

Outcome measures: The following measurements were obtained in triplicate from the consenting subjects: weight, waist, calf, chest and neck circumference, mid upper-arm circumference (MUAC), supine length, upper-arm length and wrist circumference. The age of the subject, time elapsed since injury, level of injury and level of spasticity were recorded.

Results: Body weight correlated significantly with waist, calf, chest and neck circumference and MUAC with respective Pearson correlation coefficient values (R) of 0.85 or higher and significant levels (p-values) of $p < 0.0001$. A regression equation to estimate weight was chosen on the basis of strength and practicality and included the following variables: circumferences of the calf, chest, and neck as well as the supine length. The regression equation was significant ($p < 0.0001$).

Conclusion: A regression equation was developed which could be used, when further validated, to estimate the weight of black South African paraplegic males.

S Afr J Clin Nutr 2008;21(3):127-131

Introduction

Anthropometric data plays an important role in the evaluation of nutritional status as it characterises persons with unusual properties of stature, weight, body fat and muscle percentage. However, persons with spinal cord injury (SCI) have a reduced physical capacity which changes their body composition.[1] A lesion of the spinal cord leads to denervation of the muscles below that lesion, which leads to disuse atrophy and a loss of lean body mass. This loss of lean body mass has been associated with a lower metabolic rate.[2] Another factor that influences lean body mass in some SCI persons is spasticity.[3] Spasticity refers to the involuntary muscle contraction below the level of injury that results from lack of inhibition from the higher central nervous system. Lean mass appears to be better maintained in persons with spasticity when compared to individuals with flaccid paralysis. Spasticity is more common in the acute paraplegic patient, but can still be present in the stable paraplegic person.[4] It has been reported that resting metabolic rate of spinally injured subjects does not differ from that of healthy controls after adjusting for fat free mass.[5] The average fat percentage and fat mass were reported to be significantly higher in sedentary spinal cord injured persons compared to active spinal cord injured persons.[6] The decreased energy expenditure of spinal cord injured subjects can mainly be explained by the lower levels of spontaneous physical activity.[7] A spontaneous increased energy intake8 together with a general immobility of spinally injured subjects may predispose such individuals to overweight and obesity. In this regard, it has been reported that paraplegia is associated with an increased incidence of coronary heart disease and type II diabetes at a younger age when compared with that of the able-bodied population. In addition to the risk for diseases of lifestyle, obesity is known to increase the risk for developing pressure ulcers and reduces independence in transfer activities.[1]

Although it would appear that overweight and obesity is of greater concern than underweight in the paraplegic person,[1,9,10] the latter should not be overlooked. SCI individuals are particularly susceptible to pressure ulcers. Patients with pressure ulcers have increased protein and energy needs due to the increased need for wound healing and tissue epithelialisation, a catabolic state which, in the longer term, may predispose to underweight.[11] Other causes of underweight among such individuals include depression and physical difficulties in the preparation and eating of food.[12]

It is therefore important to monitor the nutritional status of these patients to prevent malnutrition and to implement effective nutritional interventions, when necessary. In this clinical setting, monitoring of weight forms part of the routine evaluation of nutritional status since it is used as the basis for the calculation of daily protein and energy requirements. Specialised equipment is however needed to weigh paraplegic persons, such as a sitting scale, platform wheelchair scale or bed scale. Unfortunately the availability of such equipment in developing countries is limited and in such circumstances a regression equation to estimate weight from surrogate anthropometric measurements might prove to be very useful. Similar equations have been developed for able-bodied adults but not yet for paraplegic persons.[13] The aim of this study was to develop such an equation for black South African paraplegic males attending the paraplegic clinic of Kalafong Hospital, Tshwane, South Africa.

Methods

This was a cross-sectional study. Subjects (n = 43) were recruited from the paraplegic outpatient clinic of Kalafong Hospital, Tshwane, in South Africa. All subjects who attended the spinal clinic during the study period from November 2004 to March 2005 and who complied with the inclusion criteria were included in the study.

The following inclusion criteria were used: 1) black males, 18 to 60 years of age, 2) paraplegics with a level of injury of T2–L3, 3) paraplegics with a complete lesion (total absence of sensory and motor function below the level of injury), and 4) the injury should have occurred more than one year prior to the day of the current investigation. This time span was chosen as the most significant changes in body composition would have occurred after a year had elapsed since injury.[2] Changes in body composition have been reported to follow a log curve that levels off between one to three years after injury.[14]

Exclusion criteria included the following: 1) subjects with a level of injury above T2, 2) subjects with an incomplete lesion, 3) subjects of the white, coloured and Indian ethnic groups, 4) subjects with amputations, 5) subjects with oedema, 6) subjects with contractures that prevented accurate measurement of one or more of the selected parameters in the study, 7) subjects younger than 18 years of age, and 8) females. Some of the exclusion criteria reflected the characteristics of the majority of the population served by the clinic in which the study was implemented.

Study outcomes

During the study, 12 variables were assessed for possible inclusion in a regression equation to estimate the body weight of paraplegic persons. The following anthropometric measurements formed part of the 12 parameters: upper-arm length, chest, neck, wrist and calf circumference, supine length, waist and mid upper-arm circumference (MUAC). The other parameters recorded included age, time since injury, level of injury and level of spasticity.

Reproducibility of anthropometric measurements was evaluated by calculating the technical error of measurement (TEM).[15] This was obtained by carrying out two repeat measurements on the same subject in 10 subjects.

Procedures

The study was approved by the Committee for Human Research of the Faculty of Health Sciences, Stellenbosch University. After providing written informed consent, the following demographic data were recorded for each subject: age, time since injury and level of injury. Subjects were then weighed, using a platform electronic wheel chair scale (SCALES 2000; Electronic digital wheel chair platform scale, Model WCS, Durban, South Africa). Standard methods were used to take the anthropometric measurements of the subjects.[13,16,17,18] It was possible to measure the right side of all the subjects. The following measurements were taken while the subjects were sitting in their wheel chairs: upper-arm length[13] and chest,[18] neck,[18] wrist,[13] and calf circumference.[13] All the subjects were able to transfer themselves, without assistance, from their wheel chairs onto the examination bed where the supine length,[13] waist[18] and MUAC[17] of the subjects were measured. Some subjects had increased muscle tone in their legs due to spasticity. The researcher straightened their legs, while they were lying in the supine position, in order to measure supine length. The weight of the wheelchair was weighed by placing the wheelchair on the electronic digital wheelchair platform scale while the subject was lying on the examination bed. The weight of the subject was determined by subtracting the weight of the chair from the weight-plus-subject.[17] All anthropometric measurements were taken in rotational order and repeated three times. The average of the three measurements was calculated and used in the data analysis.[16] The modified Ashworth scale was used to classify spasticity (Appendix 1).[3] This is the most frequently used scale to classify spasticity at Kalafong Hospital. The scale has an inter-rater correlation of 0.847 (Kendall's r-correlation).[19]

Data analysis

Multiple stepwise linear regression was used to analyse the relationship between weight as the dependent variable, and age, time since injury, level of injury, level of spasticity, supine length, upper-arm length, MUAC, chest, wrist, neck, waist and calf circumference as the independent variables. The level of significance was set at $p < 0.05$ and applied to all tests. The software program Statistica[20] was used to develop the estimation formula and to evaluate its accuracy. Descriptive statistics were used to describe the characteristics of the population.

Results

The R value (coefficient of reliability) of two repeated measurements was calculated for the repeatability study and was 1 for measuring the weight of subject-plus-wheelchair and also for the weight of the wheel chair alone (Table I). This indicated that the repeatability of the scale to measure the same weight twice was acceptable. The R value for all the other measurements was 0.999 or higher, which is also an acceptable correlation.

Table I: Results of the repeatability study

Measurement	Technical error of measurement	Coefficient of reliability (R)
Weight: subject-plus-chair (kg)	0.012 (kg)	1.000
Weight: chair (kg)	0.002 (kg)	1.000
Upper-arm length (cm)	0.026 (cm)	0.999
Waist circumference (cm)	0.153 (cm)	0.999
Calf circumference (cm)	0.046 (cm)	0.999
Chest circumference (cm)	0.125 (cm)	0.999
Neck circumference (cm)	0.112 (cm)	0.999
Wrist circumference (cm)	0.017 (cm)	0.999
Supine length (cm)	0.121 (cm)	0.999
MUAC (cm)	0.049 (cm)	0.999

Of the possible 62 black male paraplegics who attended the clinic at the time of the study, four subjects had to be excluded due to amputations, five subjects had had their injuries for less then a year, three subjects chose not to take part in the study and seven subjects did not attend the clinic during the time of the study. There were 43 subjects who complied with the inclusion and exclusion criteria of the study. The mean age of the 43 subjects was 37.2 years (± 12.4) (range 18–60 years). The duration of the subjects' SCI ranged from one to twenty-seven years prior to the study (8.3 ± 7.1 years). No subjects had an injury level of T2 or L3 and the highest number of subjects with the same level of injury was 7, for levels T12 and T4. Many of the subjects of this study did not have spasticity (n = 15). The remainder of the subjects did have level 1 (n = 11), level 1+ (n = 4), level 2 (n = 6) and level 3 (n = 7) spasticity on the modified Ashworth scale.

The correlations between the 12 variables assessed in this study and the weight of patients were in the range of 0.89 to a negative correlation of -0.09 (Table II). Waist circumference had the strongest correlation with weight (R = 0.89). Calf, chest, arm and neck circumferences all had a correlation of 0.85 and higher. The following variables were significantly ($p < 0.05$) correlated with weight: circumferences of the waist, calf, chest, arm, neck and wrist as well as supine length and upper-arm length. The level of injury, level of spasticity, time since injury and age did not correlate significantly with weight (R < 0.26).

TableII: The correlation between the patient's actual weight and the variables measured in the study

Variable	R square	Pearson correlation coefficient (R)	p-value
Waist circumference (cm)	0.794	0.89	< 0.0001
Calf circumference (cm)	0.786	0.88	< 0.0001
Chest circumference (cm)	0.756	0.87	< 0.0001
MUAC (cm)	0.748	0.86	< 0.0001
Neck circumference (cm)	0.735	0.85	< 0.0001
Wrist circumference (cm)	0.564	0.75	< 0.0001
Supine length (cm)	0.314	0.56	< 0.0001
Upper-arm length (cm)	0.140	0.37	0.0135
Age (years)	0.069	0.26	0.0879
Level of injury	0.066	-0.25	0.0953
Time since injury (years)	0.012	0.10	0.4927
Level of spasticity	0.009	-0.09	0.5493

Practicality, strength of the relationship, adjusted R square and standard error of estimate were considered when choosing the ideal regression equation to estimate weight. This was necessary because the more variables there are in a regression equation, the more complex the equation and the more impractical it becomes for use in clinical practice.

The strength of the relationship between the predicted weight using the regression equation and the actual weight of the subjects was evaluated using the square of the multiple correlation coefficient, also called the R square value. The closer to 1, the more the variation of weight was explained by the equation. The R square value of the regression equation, using all 12 variables, was 0.977. If only one variable was to be used to develop a regression equation, the equation using waist circumference had the best R square value (0.794). For each equation with a different number of variables (from 1 to 12), there was a different R square value (Table III). There are many combinations of different variables and different numbers of variables to develop regression equations. Only the equations which had the best R square values are listed in Table III.

Table III: Statistical analysis of regression equations, using different numbers of variables in each equation

Number of variables per equation	Which variables were used	R square	Adjusted R square	Standard error of estimate (kg)
2	Circumferences (calf, chest)	0.916	0.912	4.46
3	Circumferences (calf, chest), supine length	0.954	0.950	3.35
4	Circumferences (calf, chest, neck), supine length	0.965	0.961	2.97
5	Circumferences (waist, calf, chest, upper-arm), supine length	0.968	0.964	2.84
6	Circumferences (waist, calf, chest, upper-arm), supine length, upper-arm length,	0.972	0.967	2.72
7	Circumferences (waist, calf, chest, upper-arm), supine length, age, level of injury	0.975	0.970	2.61
8	Circumferences (waist, calf, chest, upper-arm, wrist), supine length, age, level of injury	0.977	0.971	2.56
9	Circumferences (waist, calf, chest, wrist, upper-arm), supine length, age, level of injury, time since injury	0.977	0.971	2.56
10	Circumferences (waist, calf, chest, neck, wrist, upper-arm), supine length, age, level of injury, time since injury	0.977	0.970	2.60
11	Circumferences (waist, calf, chest, neck, upper-arm, wrist), supine length, age, upper-arm length, level of injury, time since injury	0.977	0.969	2.64
12	Circumferences (waist, calf, chest, neck, upper-arm, wrist), supine length, age, upper-arm length, level of injury, time since injury, level of spasticity	0.977	0.968	2.68

Another criterion that needed to be considered when choosing the number of variables in a regression equation was the adjusted R square. The adjusted R square value takes into account how much of the variation in weight is explained through the equation, but it makes the necessary adjustments for the number of variables used. As the number of variables in the equation increases, the gap between R square and adjusted R square value will also increase (Table III). This is another reason why the equation with all 12 variables was not necessarily the better equation to use even if it had the highest R square value.

The standard error of estimate is a measure of the accuracy of estimations made with a regression equation. The clinical significance of the error should be weighed against the effort to carry out more measurements and the risk to measure incorrectly. The standard error of estimate decreased from 6.91 kg, using an equation with one variable, to 2.68 kg, using an equation with 12 variables (Table III).

A regression equation, using four variables, was considered the best and most practical equation to use for this study. This equation involved the following variables: calf, chest and neck circumference and supine length. The regression equation is as follows:

Y = weight (kg)* = -129.914 + 0.803 (neck circumference) (cm) + 0.651 (chest circumference) (cm) + 1.284 (calf circumference) (cm) + 0.397 (supine length) (cm)

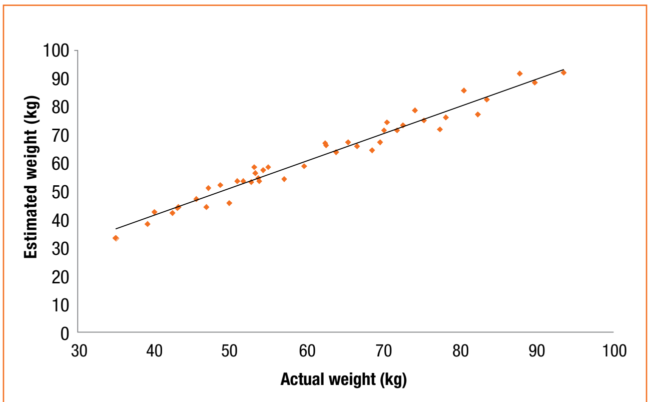
*Weight of black South African males, 18 to 60 years, level of injury of T2–L3, date of injury > one year prior to investigation, complete lesion.

The equation was chosen with the least number of variables but at the same time showing acceptable accuracy. The R square value of the four-variable equation was 0.965, the adjusted R square value 0.967 and the standard error of estimate was 2.97 kg.

The Mallows CP criterion gives an indication of how small the bias of the chosen equation is.[21] A value close to p + 1 indicates that the equation bias is small (p is the number of variables in the equation). Values near or below p + 1 are generally desirable. In the case of the four-variable equation a value of 5 or less would be desirable.[21] The Mallow CP criterion for the four-variable equation was 5.000, which indicates that the equation did have a very small level of bias.

The four-variable equation was used to calculate the predicted weights of the subjects in this study which were then compared to their actual weights (Figure 1). The line indicated on the graph is where estimated weight equals actual weight (x = y). The closer to the line the points are, the more accurately the weight was estimated.

Figure 1: The comparison between the estimated weight and the actual weight of the subjects of the study



Y = weight (kg) = -129.914 + $0.803x_1$ + $0.651x_2$ + $1.284x_3$ + $0.397x_4$
r^2 = 0.965 p = 0.000
X_1 = neck circumference (cm), X_2 = chest circumference (cm), X_3 = calf circumference (cm), X_4 = supine length (cm)

Discussion

In this study a regression equation with an acceptable degree of predictability has been formulated using a relatively small number of SCI patients to assess the weight of black male paraplegics in an academic hospital in South Africa. Such an estimate has not been established before in a South African setting and may prove useful in the evaluation of the weight of such individuals. Certainly a more extensive validation in similar settings in the country will be needed.

Due to the lack of practical alternatives, current clinical practice is to base the calculation of protein and energy requirements of SCI patients on their body weight. Indirect calorimetry is considered the most accurate method to determine energy expenditure and therefore energy requirements. However, the equation developed in this study may be especially useful in situations where access to such expensive measures of energy expenditure is not available. The use of this equation may also obviate the use of specialised weighing equipment, which may not be available in the healthcare setting in the developing world, and could additionally be a useful tool in the early identification and treatment of malnourished paraplegic subjects as well as the risk reduction for diseases of lifestyle and pressure ulcers. Furthermore, it should be borne in mind that standards have been set for ideal body weight for able-bodied persons in the form of body mass index,[22,13] with the ideal body weight of a paraplegic person being 4.5 kg to 6.5 kg below the ideal body weight of an able-bodied person of the same height due to disuse atrophy.[12] The standards that exist for ideal body weight of paraplegic people, however, are of little value if their weight cannot be accurately determined.

The simplicity of taking the four measurements to estimate weight is a definite advantage of the four-variable equation. Only a tape measure is needed to carry out the measurements. Neck, chest and calf circumferences can be taken while the subject is seated in the wheelchair. Supine length, however, needs to be taken on an examination bed.

Regression analysis is a widely used method to estimate the value of a dependent variable from various independent variables.[13,23,24] Regression analysis has often been used to estimate a measurement where it is not possible to take the measurement directly. Regression equations have been developed to estimate various measurements of paraplegic persons, due to their inability to stand or walk.[13,25,26,27] According to Heyward and Stolaczyk, good estimation equations have several characteristics[16]: 1) use of acceptable reference methods to obtain criterion measures of body composition, 2) use of large randomly selected samples (n > 100), 3) high multiple correlation between the reference measure and estimated scores (R > 0.80), 4) small prediction of standard error of estimate, and 5) cross-validation of the equation on additional, independent samples from the population. In this study acceptable reference methods were used to obtain the actual weight of the subjects. The regression relation between actual and estimated weight was higher than 0.80. The standard error of estimate was small (2.97 kg).

However, the equation has important limitations in that the sample size was far less than 100 and the study was done on black male South African paraplegics only. Therefore the equation has limited generalisibility to the broader paraplegic population. The equation was also not cross-validated in an independent sample of the population, and the level of injury was not taken into account when predicting the weight of the subjects. Other factors that could have had an influence on the weight of the subjects and that were not taken into account in this study are the weight of a subject's trousers, dehydration and the presence of possible faecal mass.[13] Physical exercise, known to increase lean body mass, which is denser than the same volume of fat mass,[22] was also not taken into account in this study. Subjects who exercise and have stronger upper bodies might, therefore, have their weight under-estimated if the equation was used without further validation.

It should also be borne in mind that supine length was measured in this study instead of height due to the inability of the subjects to stand. When the ideal body weight of an adult is calculated, height and not length is used to do the calculations.[13] In a study by Gray (1985), there was a significant difference of 2% between standing height and supine length. In that study the supine length of the subjects was on average 3.68 cm longer than their standing height.[28] The compression of the spinal vertebrae in the standing position is the reason for the difference between the two measurements.[28] This small but systematic error may result in the misinterpretation of the nutritional status of an individual. Another recommendation could be to investigate the use of knee height in the equation instead of supine length, as this is also a simple but accurate way of determining height.[13]

It can be concluded that the chosen four-variable regression equation may be useful in the estimation of the weight of black South African paraplegic persons with the same characteristics as the sample in this study. However, results need to be confirmed by further research on larger groups and different ethnic and gender groups. Future studies should also investigate the accuracy of energy requirements based on body weight equations as compared to measurement of energy expenditure by indirect calorimetry.

It can be concluded that the chosen four-variable regression equation can be implemented in institutions to estimate the weight of a paraplegic person with the same characteristics as the sample in this study. Results need to be confirmed by further research on larger groups and different ethnic and gender groups.

Appendix 1

Modified Ashworth scale: [3]

0 If there is no increase in muscle tone.

1 If there is a slight increase in muscle tone, manifested by minimal resistance at the end of the range of motion (ROM) when the affected part(s) is moved in flexion or extension.

1+ If there is a slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM.

2 If there is a more marked increase in muscle tone through most of the ROM, but affected part(s) is easily moved.

3 If there is a considerable increase in muscle tone and passive movement is difficult.

4 If the effected part(s) is rigid in flexion or extension.

References

1. Kocina P. Body composition of spinal cord injured adults. Sports Medicine 1997;23(1):48–60.
2. Nuhlick RDN, Spurr GB, Barboriak JJ, Booney CB, Elghatit AZ, Bongard RD. Body composition of patients with spinal cord injury. Eur J Clin Nutr 1988;42:765–773.
3. Mathiowetz H, Haugen JB. Evaluation of motor behaviour: traditional and contemporary views. In: Trombly CA, ed. Occupational therapy for physical dysfunction. 4th ed. Baltimore: Williams & Wilkins; 1995. 167–170.
4. Wilmet E, Ismail AA, Heilporn A, Welreads D, Bergmann P. Longitudinal study of bone mineral content and soft tissue composition after spinal cord section. Paraplegia 1995;33:674–677.
5. Buchholtz AC, McGillivray CF, Pencharz PB. Differences in resting metabolic rate between paraplegic and able-bodied subjects are explained by differences in body composition. Am J Clin Nutr 2003;77:371–378.
6. Olle MM, Pivarnik JM, Klish WJ, 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.
7. Monroe MB, Tataranni PA, Pratley R, Manore MM, Skinner JS, Ravussin E. Lower daily energy expenditure as measured by a respiratory chamber in subjects with spinal cord injury compared with control subjects. Am J Clin Nutr 1998;68:1223–1227.
8. Cox SAR, Weiss SM, Posuniak EA, Worthington P, Prioleau M, Heffley G. Energy expenditure after spinal cord injury: evaluation of stable rehabilitating patients. J Trauma 1985;25:419–423.
9. 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;36:637–640.
10. Jones LM, Legge M, Goulding A. Healthy body mass index values often underestimate body fat in men with spinal cord injury. Arch Phys Med Rehabil 2003;84:1068– 1070.
11 Breslow RA, Bergstorm N. Nutritional prediction of pressure ulcers. J Am Diet Assoc 1994;94:1301–1304.
12. Rodwell WS. The physically disabled. In: Thomas B, ed. Manual of dietetic practice. 2nd ed. London: Blackwell Scientific Publishers; 1988. 318–320.
13. Lee RD, Nieman DC. Anthropometry. In: Nutritional assessment. 3rd ed. London: McGraw Hill; 2003:164–5,182–3, 223–225.
14. Zehner Y, Luthi M, Michel D, et al. Long-term changes in bone metabolism, bone mineral density, quantitative ultrasound parameters, and fracture incidence after spinal cord injury. Osteoporosis Int 2004;15(3):180-189.
15. Ulijaszek SJ, Kerr DA. Anthropometric measurement error and the assessment of nutritional status. Br J Nutr 1999;82:165–177.
16. Heyward VH. Practical body composition assessment for children, adults, and older adults. Int J Sport Nutr 1998;8:285–307.
17. Skipper, A. Anthropometric data in nutrition support, policies, procedures, forms and formulas. Maryland: Aspen publishers; 1995. 47– 87.
18. Ross WD, Marfell-Jones MT. Kinanthropometry. In: MacDougall JD, Wenger HA, Green HJ, eds. Physiological testing of the high-performance athlete. 2nd ed. Champaign: Illinois; 1991. 223–308.
19. Priebe MM, Sherwood AM, Thornby JI, Kharas NF, Markowski J. Clinical assessment of spasticity in spinal cord injury: a multidimentional problem. Arch Phys Med Rehab 1996;77:713–716.
20. Statsoft Inc. STATISTICA data analysis software system, version 7. www.statsoft.com; 2004.
21. Neter J, Kutner MH, Nachtsheim CJ, Wasserman W, eds. Applied linear models. 4th ed. Irwin, Chicago; 1996. 341–345.
22. Hammond KA. Dietary and clinical examination. In: Mahan K, Escott-Stump S, eds. Food, nutrition and diet therapy. 11th ed. Washington: Saunders; 2004. 421–7, 580–581.
23. Frey-Rindova P, De Bruin ED, Stussi E, Dambacher MA, Dietz V. Bone mineral density in upper and lower extremities during 12 months after spinal cord injury measured by peripheral quantitative computed tomography. Spinal Cord 2000;38:26–32.
24. Deurenberg P, Westrate JA, Seiden JC. Body mass index as a measure of body fatness: age- and sex-specific prediction equation formulas. Br J Nutr 1991;65:105–114.
25. Jarzem PF, Gledhill RB. Predicting height from arm measurements. J Peadiatr Orthop 1993;13(6):761–765.
26. Chen C, Yeung K, Bih L, Wang C, Chen M, Chien J. The relationship between sitting stability and functional performance in patients with paraplegia. Arch Phys Med Rehabil 2003;84:1276–1281.
27. Vinet A, Le Gallias D, Bouges S, Bernard P-L, Varray A, Micallef J-P. Prediction of VO2 peak in wheelchair-dependent athletes from the adapted Leger and Boucher test. Spinal Cord 2002;40:507–512.
28. Gray DS, Crider JB, Kelley C, Dickinson L C. Accuracy of recumbent height measurement. J Parenter Ent Nutr 1985;9:712–715.