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Original Research

Sarcopenia among Adults with Cerebral Palsy in South Korea

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Abstract

Background: Most adults with cerebral palsy encounter newly developing physical health problems and premature functional decline with aging. These physical and functional losses along with the characteristic symptoms of cerebral palsy may heighten the risk of sarcopenia.
Objective: To determine the prevalence of sarcopenia among a selected group of adults with cerebral palsy and to identify the factors associated with their sarcopenia among them.
Design: Cross-sectional study.
Setting: University hospitals and communities for persons with disabilities.
Participants: A total of 80 adults with cerebral palsy (46 men and 34 women with mean age of 42.8 $\pm$ 8.86 years) were included.
Method: Muscle mass, strength, and physical performance were measured to diagnose sarcopenia. Participants also completed a structured questionnaire for physical, psychological, or socioeconomic attributes and health-related quality of life.
Main Outcome Measures: Prevalence of sarcopenia in adults with cerebral palsy.
Results: The prevalence of sarcopenia was 47.9%. Sarcopenia was significantly associated with sex, the Gross Motor Function Classification System (GMFCS), the Manual Ability Classification System (MACS), body mass index (BMI), and trunk fat. Male, higher GMFCS and lower BMI were significant risk factors of sarcopenia. Sarcopenic adults with cerebral palsy showed significantly lower health-related quality of life.
Conclusion: The prevalence of sarcopenia in adults with cerebral palsy was higher than that of general population despite the young age of the selected group. Modifiable risk factor was a low BMI.
Level of Evidence: III

Introduction

Cerebral palsy (CP) is a group of permanent disorders of movement and posture that cause activity limitation, which are attributed to nonprogressive injuries that had occurred to the immature brain. It is the most common motor disability in childhood, with prevalence estimates ranging from 1.5 to 2.5 per 1000 live births.[1-3] Similar to other childhood-onset disabilities and illnesses, medical attention has usually focused on the health issues in infancy and childhood in people with CP.

However, the lifespan of individuals with CP is approaching that of the general population.[4] By definition, the neurological problem in CP is nonprogressive. However, persons with CP experience a premature decline in mobility and function as they age.[5] Their aging process may be accelerated compared to that of neurotypical persons because of a cycle of deconditioning, in which physical dysfunction is followed by decreased physical activity, followed by further functional decline.[5,6] One of the grave changes associated with aging is sarcopenia.[7] Sarcopenia is a syndrome characterized by a progressive and generalized loss of skeletal muscle mass and strength with the risk of adverse outcomes such as increased risk of falls and fractures, increased risk of hospitalization, loss of independence, and increased mortality.[7] This decline in muscle mass begins in the mid-twenties, and sarcopenia may occur earlier in adults with

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CP than among normally developing adults.[5] Individuals with CP have compromised muscle function because of neurological inability to move muscles efficiently.[8,9] These factors may predispose young adults with CP to experience secondary muscle wasting and physical functional decline reminiscent of age-related sarcopenia.[6]

To our knowledge, the number of adults with CP who have sarcopenia and the associated factors have not been investigated yet. Therefore, we aimed (1) to investigate the prevalence of sarcopenia and (2) to identify the factors associated with the sarcopenia in a selected group of adults with CP in South Korea.

Materials and Methods

Study Population

In this cross-sectional study, we recruited adults with CP aged 20 years or older. We used 20 as an age cutoff as 20 is considered the legal age of adulthood In South Korea. Participants were recruited from the community with the cooperation of nationwide organizations of persons with disabilities as well as from four hospitals in Gyeonggi and Seoul in South Korea. We prospectively identified and contacted 243 individuals with CP to participate in the study. Participants were excluded if they could not understand or answer the questionnaire despite receiving assistance from an interviewer, if they failed to be assessed using dual-energy x-ray absorptiometry (DXA), or if they withdrew prior to data collection. Data were collected between February 1, 2014 and November 31, 2014.

Assessment Procedure

All the study procedures were approved by the institutional review boards of the participating institutions operating in compliance with the Guidelines for Good Clinical Practice. Written informed consent was obtained from all the participants was obtained. After consent of the participants was obtained, questionnaire surveys, assessments, and measurements were conducted.

A structured interview was conducted by a physiatrist or a trained research nurse to complete the questionnaire regarding demographics, physical function, emotional or psychological attributes, socioeconomic attributes, and health-related quality of life (HRQOL). The questionnaire included sex, age, the presence of a living spouse and family living with the patient, years of formal education, monthly income, and employment status. It also included the type of CP, gross motor function, manual ability, habitual smoking or drinking, and history of fracture and falls.

Researcher-Collected Data and Tests

The Gross Motor Function Classification System (GMFCS) and the Manual Ability Classification System (MACS) were used to evaluate gross motor and upper limb function in this study. The GMFCS is widely used to describe abilities and limitations in gross motor function including sitting and walking in children aged up to 18 years with CP.[10] The MACS classifies how well children with CP aged 4 to 18 years use their hands when handling objects in daily activities.[10] Both are designed to reflect the child's typical performance, not the maximal capacity.[10] These are five-level systems where level I represents the least limitation and level V the most.[10] A physiatrist evaluated each participant and rated them using the GMFCS and the MACS. The type of CP was also determined by a physiatrist after clinical examination.

To measure appendicular skeletal muscle mass and percentage of trunk fat, DXA (GE Lunar Prodigy, Bedford, MA) was used. DXA is widely considered as the "gold-standard" method in the diagnosis of sarcopenia, because it provides a precise evaluation of body composition at low cost and with excellent availability.[11] Appendicular skeletal muscle mass (ASM) was then divided using the square of height. Hand-grip strength was measured by a trained physical therapist with the Jamar Hydraulic dynamometer, in pounds. The Short Physical Performance Battery (SPPB) is a composite measure of physical performance which evaluates balance, gait, strength, and endurance.[7] The SPPB was also assessed by a physical therapist.

Laboratory analysis was performed to measure total cholesterol and triglyceride, high-density lipoprotein, and low-density lipoprotein levels as metabolic syndrome is known to be associated with sarcopenia, especially sarcopenic obesity.[12] Whole-spine x-ray scan was also performed to evaluate scoliosis.

Participant-Reported Outcome Measures

Emotional and psychological features, such as depression, pain, and fatigue, were assessed using the Beck Depression Inventory, Brief Pain Inventory, and Brief Fatigue Inventory. HRQOL was evaluated with the European Quality of Life 5 Dimensions Questionnaire 3-Level version (EQ-5D-3 L), which has been validated and widely used in people with physical or cognitive disabilities. The EQ-5D-3 L index could be calculated using the time trade-off (TTO) method introduced by Lee et al.[13] Information about comorbidities, including diabetes mellitus, hypertension, dyslipidemia, and obesity, was also collected.

Definition of Sarcopenia

Sarcopenia was defined as low muscle mass and low muscle function (strength or performance) according to the European Working Group on Sarcopenia in Older People (EWGSOP).[7] The cutoff values for sarcopenia diagnosis were adopted from the consensus report of the Asian Working Group for Sarcopenia (AWGS) in 2014.[14] The AWGS recommends using height-adjusted skeletal muscle mass (ASM divided by the square of height) and cutoff values of 7.0 kg/m^2 for men and 5.4 kg/m^2 for women.

For muscle strength, the cutoff points of low hand-grip strength were < 26 kg (57.32 lb) for men and < 18 kg (39.68 lb) for women. The parameters for physical performance usually include wide range of tests such as the SPPB, usual gait speed, and 6-min walk test. Among these, we used SPPB in consideration of nonambulatory subjects who are not eligible for gait measures.[15] The cutoff value of SPPB was <9 points, which was suggested by EWGSOP.

Statistical Analysis

All statistical analyses were conducted with SPSS ver. 20.0 (SPSS Inc, Chicago, IL). Descriptive statistics were calculated and summarized. Univariate analyses were performed for all the variables to select independent factors associated with sarcopenia.

A multivariate logistic regression analysis was used to investigate the factors associated with sarcopenia. Stepwise and backward elimination algorithms were used to search for a set of variables with maximum discriminatory power.[16] As multicollinearity among the independent variables may reduce the variance estimated in the regression model, a multicollinearity diagnosis that uses a variance inflation factor of <10 was conducted prior to exploring the predictors. Statistical significance was accepted at $P < .05$. Factors with significance levels of <.10 were excluded from the regression model. Model adequacy was assessed using an analysis of residuals.

Results

Characteristics of Sarcopenia among Adults with CP

The study population consisted of 80 adults (46 men) with CP (Figure 1), with the mean age of 42.8 ± 8.86 (22-68) years. Among the final 80 participants, the measure of hand-grip strength and the SPPB data were missing for 7 participants. Table 1 shows the distribution of the types of CP and GMFCS.

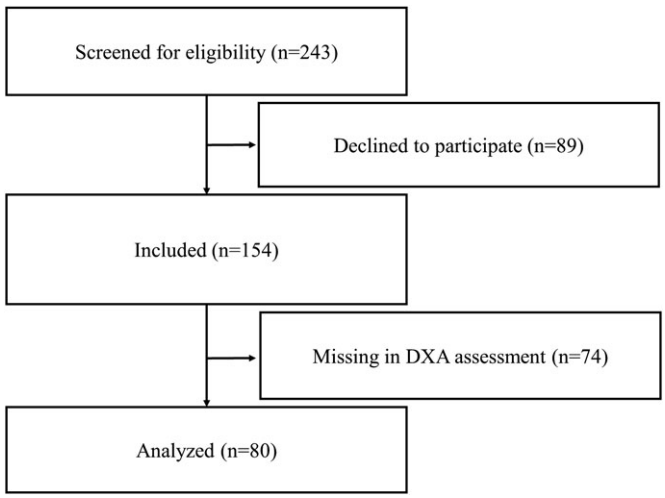

Figure 1. Enrollment flowchart for study population. Abbreviations: DXA, dual-energy x-ray absorptiometry.

The mean ASM was 15.7 ± 3.62 kg and the mean ASM/ht^2 was 6.16 ± 1.20 kg/m^2 (P value of the Shapiro-Wilk test = .37 and .91). The ASM/ht^2 was significantly higher in men (6.59 ± 1.22 kg/m^2) than in women (5.57 ± 0.883 kg/m^2, P value <.001) and was significantly higher in ambulatory individuals (6.51 ± 0.89 kg/m^2, 19 men and 18 women with GMFCS levels I-III) than nonambulatory individuals (5.85 ± 1.35 kg/m^2, 27 men and 16 women with GMFCS levels IV and V, $P = .01$). The ASM/ht^2 was in the ambulatory group was 7.17 ± 0.545 kg/m^2 in men and 5.82 ± 0.601 kg/m^2 in women, and 6.18 ± 1.40 kg/m^2 in men and 5.29 ± 1.07 kg/m^2 in women in the nonambulatory group.

There was a positive correlation between the ASM/ht^2 and hand-grip strength (Pearson r values with log(hand grip): 0.562 ($P < .001$) but no significant correlation was found between the ASM/ht^2 and the SPPB.

Sarcopenia was defined as low muscle mass (measured with the ASM/ht^2) and low muscle function (decreased muscle strength measured with hand-grip strength or decreased physical performance measured with the SPPB). By this definition, 37 subjects (26 men and 9 women, 47.9%) were diagnosed with sarcopenia. The prevalence of sarcopenia was higher in men (65.9%) than in women (28.1%). The prevalence of sarcopenia did not differ by age, the type

Table 1
The distribution of the types of cerebral palsy and the Gross Motor Function Classification System (GMFCS)

Type	Spastic	33.8
	Mixed	32.5
	Dystonic	16.3
	Athetoid	8.8
	Others	8.6
GMFCS	I	12.5
	II	28.7
	III	5.0
	IV	50.0
	V	3.8

All values are %.

Table 2
Adjusted appendicular skeletal muscle masses (ASM) and prevalence of sarcopenia for adults with cerebral palsy in South Korea according to age and sex

	Number of Subjects	ASM/Height^2 (kg/m^2)*	Sarcopenia (%)
Men			
<40	20	6.50 ± 1.12	65.0
40~49	17	6.97 ± 1.13	53.8
≥50	9	6.08 ± 1.50	77.8
Women			
<40	15	5.65 ± 0.681	20.0
40~49	15	5.82 ± 0.843	15.4
≥50	4	4.31 ± 0.785	100.0

*Mean ± SD.

of CP, or the geographic type. The prevalence of sarcopenia according to sex and age is shown in Table 2.

Factors Associated with Sarcopenia in Adults with CP

In addition to the demographic factors, socioeconomic, CP-related, physical, and psychological factors were analyzed. The distribution of these factors in patients with sarcopenia is shown in Table 3. Among these factors, the correlated variables were sex (P = .005), the GMFCS level (P < .001), the MACS level (P = .02), body mass index (BMI; P = .001), and percentage of trunk fat (P = .02).

These 5 variables were entered into the multiple logistic regression model and the percentage of trunk fat was eliminated using stepwise backward elimination. By the multiple logistic regression analysis, the associated factors of sarcopenia included male sex (adjusted odds ratio [OR]; 95% confidence interval [CI]: 7.69; 1.83-32.3; P = .005),

Table 3
Characteristics of study population with or without sarcopenia

	Sarcopenia	No Sarcopenia	*P* Value
Male	27 (75.0%)	14 (37.8%)	.005*
Age (years)	44.1 ± 10.1†	40.4 ± 8.1	.09
Living Spouse	9 (26.5%)	10 (25.6%)	.94
Family living together	19 (59.4%)	23 (59.0%)	.97
Education years, median (IQR)	4 (1-7)‡	4 (2-6)	.09
Monthly income			.09
<885 USD	23 (67.6%)	18 (46.2%)	
885~1770 USD	8 (23.5%)	15 (38.5%)	
1770~2655 USD	3 (8.8%)	6 (15.4%)	
Employed status	18 (52.9%)	19 (48.7%)	.72
Type of cerebral palsy			.54
Spastic	10 (30.3%)	14 (35.9%)	
Mixed	14 (42.4%)	10 (25.6%)	
Dystonic	4 (12.1%)	8 (20.5%)	
Athetoid	2 (6.1%)	4 (10.3%)	
Others	3 (9.1%)	3 (7.7%)	
Gross Motor Function Classification System			<.001*
I	0 (0%)	9 (23.1%)	
II	6 (17.6%)	14 (35.9%)	
III	3 (8.8%)	1 (2.6%)	
IV	23 (67.6%)	14 (35.9%)	
V	2 (5.9%)	1 (2.6%)	
Manual Ability Classification System			.02*
I	1 (2.9%)	0(0%)	
II	16 (47.1%)	28 (71.8%)	
III	7 (20.6%)	8 (20.5%)	
IV	2 (5.9%)	1 (2.6%)	
V	8 (23.5%)	2 (5.1%)	
Smoking	6 (18.8%)	6 (17.1%)	.86
Drinking	17 (53.1%)	21 (60.0%)	.57
Fracture history	8 (23.5%)	14 (35.9%)	.25
Fall-down history	18 (54.5%)	25 (71.4%)	.15
Diabetes Mellitus	2 (5.9%)	2 (5.1%)	>.99
Hypertension	4 (11.8%)	2 (5.1%)	.41
Dyslipidemia	3 (8.8%)	3 (7.7%)	>.99
Scoliosis	18 (56.3%)	22 (56.4%)	.99
Total cholesterol (mg/dL)	181 ± 37.8†	171 ± 28.5	.16
Triglyceride (mg/dL)	112 (48-446)‡	107 (41-435)	.49
High-density lipoprotein (mg/dL)	44.5 (31-69)	48 (28-88)	.17
Low-density lipoprotein (mg/dL)	105 ± 29.1	96.1 ± 25.6	.16
Body mass index (kg/m^2)	20.5 (14.9-39.2)	24.2 (16.7-35.3)	.001*
Trunk fat (%)	28.3 ± 11.0	34.6 ± 11.5	.02*
Waist circumference (cm)	77.8 (63.5-140)	82.0 (51.0-104)	.38
Beck Depression Inventory	15.5 (0-37)	13.5 (0-51)	.07
Brief Pain Inventory	17.4 ± 8.28	18.7 ± 8.96	.52
Impact of pain	39 (5-69)	39 (0-70)	.99
Brief Fatigue Inventory	18 (4-27)	17 (0-30)	.73
Impact of fatigue	30.8 ± 14.5	29.5 ± 14.3	.71

†Mean ± SD.
‡Median interquartile range.

Table 4
Factors associated with sarcopenia using multiple logistic regression analysis

Variable	OR	95% CI		*P* Value
		Lower	Upper	
Male	7.69	1.83	32.3	.005*
Gross Motor Function Classification System	2.37	1.32	4.24	.004*
Manual Ability Classification System	1.91	0.971	3.75	.06
Body Mass Index	0.840	0.733	0.964	.01*
Nagelkerke R^2	0.516			
Hosmer-Lemeshow test	0.248			

poor GMFCS level (2.37; 1.32-4.24; $P = .004$), and lower BMI (0.840; 0.733-0.964; $P = .013$, $R^2 = 0.516$; Table 4).

Sarcopenia and Health-Related Quality of Life in Adults with CP

To assess the effect of sarcopenia on HRQOL, EQ-5D-3 L-TTO was measured. In the Student *t*-test, individuals with sarcopenia showed significantly lower EQ-5D-3 L-TTO scores than those without sarcopenia (0.442 vs 0.634, $P = .007$).

Discussion

We found that sarcopenia affects 47.9% of this selected group of adults with CP in South Korea. Men are more vulnerable to sarcopenia than women, and those with sarcopenia have poorer GMFCS and lower BMI. Sarcopenia was found to be significantly associated with poor HRQOL.

Recent data of general population in South Korea showed that 11.5% of men and 4.8% of women in their 40s had sarcopenia, when defined with cutoff ASM/ht^2 values of 7.50 kg/m^2 for men and 5.38 kg/m^2 for women.[17] These cutoff values were close to those used in this study. When we compared the prevalence of sarcopenia in our group (53.8% in men and 15.4% in women in their 40s) to that of general population in their 40s, the prevalence of sarcopenia was more than 3 times higher in adults with CP than in neurotypical adults.

In this study, we showed that sarcopenia is associated with male sex, poor GMFCS, and low BMI in adults with CP.

A higher prevalence of sarcopenia in men is also observed in general population.[18] In CP, impaired mobility causes chronic inactivity and sedentary behavior, which can result in loss of skeletal muscle mass.[6] Previous studies demonstrated premature functional decline in early adulthood.[19-21] The mechanism of this premature aging was suggested to be the circular cause and consequence of events of premature sarcopenia, progression of motor dysfunction, and diminished activity.[6]

Previous studies showed that sarcopenia is frequently associated with obesity, as it is termed as "sarcopenic obesity" to describe the combination of obesity and decreased muscle mass and strength.[22] However, contrary to the general elderly population, sarcopenia is associated with low BMI in this CP population. Undernutrition of CP may be the one of important factors causing skeletal muscle atrophy and impaired muscle growth.[23] People with poorer GMFCS tend to have more severe morbidity such as dysphagia, gastrointestinal dysfunction, and impaired immunity, which also may affect nutrition and resultantly muscle mass and physical performance. As BMI was the only modifiable risk factor, participation in resistance exercise or improvement in nutrition might be suggested as possible strategies for sarcopenia.

Finally, sarcopenic adults with CP have a significantly lower HRQOL. It is similar to sarcopenia among the general population.[24] Sarcopenia may be considered as one of important factors related to HRQOL of adults with CP.

Our study had some limitations that must be considered. First, the cross-sectional nature of this study did not allow us to identify the causal relationships between poor gross motor function, low BMI, and sarcopenia. A longitudinal study would be needed to investigate the causal relationships and the nature of sarcopenia in CP. Second, because 58.8% of the participants were nonambulatory with GMFCS levels of IV to V, the prevalence of sarcopenia might have been overestimated. Third, the clinical characteristics of sarcopenia are expected to be different by the type or area of involvement of CP. It was limited in this study design and study population to fully investigate the association between sarcopenia and those factors.

Despite these limitations, to our knowledge, this study is the first to report the prevalence of sarcopenia and the associated factors in adults with CP. The result of this study suggests the need for more anticipative management to prevent sarcopenia in adults with CP from a young age.

Conclusion

In this study, we found a higher prevalence of sarcopenia in adults with CP than in the general population. To our knowledge, this study is the first that examined the prevalence of sarcopenia in adults with CP. We found a significant association between sarcopenia and poor gross motor function and low BMI. Considering the increasing life expectancy of CP, strategies should be developed to manage premature sarcopenia and improve the quality of life of adults with CP.

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References

1. Paneth N, Hong T, Korzeniewski S. The descriptive epidemiology of cerebral palsy. *Clin Perinatol*. 2006;33(2):251-267.
2. Park MS, Kim SJ, Chung CY, Kwon DG, Choi IH, Lee KM. Prevalence and lifetime healthcare cost of cerebral palsy in South Korea. *Health Policy*. 2011;100(2–3):234-238.
3. Bax M, Goldstein M, Rosenbaum P, et al. Proposed definition and classification of cerebral palsy. *Dev Med Child Neurol*. 2005;47(8): 571-576.
4. Aisen ML, Kerkovich D, Mast J, et al. Cerebral palsy: clinical care and neurological rehabilitation. *Lancet Neurol*. 2011;10(9):844-852.
5. Tosi LL, Maher N, Moore DW, Goldstein M, Aisen ML. Adults with cerebral palsy: a workshop to define the challenges of treating and preventing secondary musculoskeletal and neuromuscular complications in this rapidly growing population. *Dev Med Child Neurol*. 2009;51(suppl 4):2-11.
6. Peterson MD, Gordon PM, Hurvitz EA. Chronic disease risk among adults with cerebral palsy: the role of premature sarcopoenia, obesity and sedentary behaviour. *Obes Rev*. 2013;14(2):171-182.
7. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. European Working Group on Sarcopenia in Older People. Sarcopenia: European consensus on definition and diagnosis report of the European Working Group on sarcopenia in older people. *Age Ageing*. 2010;39(4): 412-423.
8. Lampe R, Grassl S, Mitternacht J, Gerdesmeyer L, Gradinger R. MRT-measurements of muscle volumes of the lower extremities of youths with spastic hemiplegia caused by cerebral palsy. *Brain Dev*. 2006;28 (8):500-506.
9. Shortland A. Muscle deficits in cerebral palsy and early loss of mobility: can we learn something from our elders? *Dev Med Child Neurol*. 2009;51(suppl 4):59-63.
10. Carnahan KD, Arner M, Hägglund G. Association between gross motor function (GMFCS) and manual ability (MACS) in children with cerebral palsy. A population-based study of 359 children. *BMC Musculoskelet Disord*. 2007;8(1):50-50.
11. Guglielmi G, Ponti F, Agostini M, Amadori M, Battista G, Bazzocchi A. The role of DXA in sarcopenia. *Aging Clin Exp Res*. 2016;28(6):1047-1060.
12. Lim S, Kim JH, Yoon JW, et al. Sarcopenic obesity: prevalence and association with metabolic syndrome in the Korean Longitudinal Study on Health and Aging (KLoSHA). *Diabetes Care*. 2010;33(7): 1652-1654.
13. Lee Y-K, Nam H-S, Chuang L-H, et al. South Korean time trade-off values for EQ-5D health states: modeling with observed values for 101 health states. *Value Health*. 2009;12(8):1187-1193.
14. Chen LK, Liu LK, Woo J, et al. Sarcopenia in Asia: consensus report of the Asian working group for sarcopenia. *J Am Med Dir Assoc*. 2014;15 (2):95-101.
15. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on sarcopenia in older people. *Age Ageing*. 2010;39(4): 412-423.
16. Nguyen TV, Eisman JA, Kelly PJ, Sambrook PN. Risk factors for osteoporotic fractures in elderly men. *Am J Epidemiol*. 1996;144(3): 255-263.
17. Kim YS, Lee Y, Chung YS, et al. Prevalence of sarcopenia and sarcopenic obesity in the Korean population based on the Fourth Korean National Health and Nutritional Examination Surveys. *J Gerontol A Biol Sci Med Sci*. 2012;67(10):1107-1113.
18. Dodds RM, Roberts HC, Cooper C, Sayer AA. The epidemiology of sarcopenia. *J Clin Densitom*. 2015;18(4):461-466.
19. Jahnsen R, Villien L, Egeland T, Stanghelle JK, Holm I. Locomotion skills in adults with cerebral palsy. *Clin Rehabil*. 2004;18(3): 309-316.
20. Hanna SE, Rosenbaum PL, Bartlett DJ, et al. Stability and decline in gross motor function among children and youth with cerebral palsy aged 2 to 21 years. *Dev Med Child Neurol*. 2009;51(4):295-302.
21. Bottos M, Feliciangeli A, Sciuto L, Gericke C, Vianello A. Functional status of adults with cerebral palsy and implications for treatment of children. *Dev Med Child Neurol*. 2001;43(8):516-528.
22. Stenholm S, Harris TB, Rantanen T, Visser M, Kritchevsky SB, Ferrucci L. Sarcopenic obesity-definition, etiology and consequences. *Curr Opin Clin Nutr Metab Care*. 2008;11(6):693.
23. Gough M, Shortland AP. Could muscle deformity in children with spastic cerebral palsy be related to an impairment of muscle growth and altered adaptation? *Dev Med Child Neurol*. 2012;54 (6):495-499.
24. Go SW, Cha YH, Lee JA, Park HS, Lang TF, Harris TB. Association between sarcopenia, bone density, and health-related quality of life in Korean men. *Korean J Fam Med*. 2013;34(4):281-288.

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