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ORIGINAL RESEARCH

Greater Adipose Tissue Distribution and Diminished Spinal Musculoskeletal Density in Adults With Cerebral Palsy

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Abstract

Objectives: To examine differences in adipose tissue distribution, lumbar vertebral bone mineral density (BMD), and muscle attenuation in adults with and without cerebral palsy (CP), and to determine the associations between morphologic characteristics.

Design: Cross-sectional, retrospective analyses of archived computed tomography scans.

Setting: Clinical treatment and rehabilitation center.

Participants: Adults (N=352) with CP (age, 38.8±14.4y; body mass, 61.3±17.1kg; Gross Motor Function Classification System levels, I–V) and a matched cohort of neurotypical adults. Of the 41 adults with CP included in the study, 10 were not matchable because of low body masses.

Interventions: Not applicable.

Main Outcome Measures: Computed tomography scans were assessed for visceral adipose tissue (VAT) and subcutaneous adipose tissue (SAT) areas, psoas major area and attenuation in Hounsfield units (Hu), and cortical and trabecular BMDs.

Results: Adults with CP had lower cortical (β=−63.41 Hu, $P<.001$) and trabecular (β=−42.24 Hu, $P<.001$) BMDs and psoas major areas (β=−374.51mm^2, $P<.001$) and attenuation (β=−9.21 Hu, $P<.001$) after controlling for age, sex, and body mass. Adults with CP had greater VAT (β=3914.81mm^2, $P<.001$) and SAT (β=4615.68mm^2, $P<.001$). Muscle attenuation was significantly correlated with trabecular ($r=.51$, $P=.002$) and cortical ($r=.46$, $P<.01$) BMD, whereas VAT was negatively associated with cortical BMD (β=−.037 Hu/cm^2, $r^2=.13$, $P=.03$).

Conclusions: Adults with CP had lower BMDs, smaller psoas major area, greater intermuscular adipose tissue, and greater trunk adiposity than neurotypical adults. VAT and cortical BMD were inversely associated.

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Cerebral palsy (CP) is caused by a malformation or lesion to the developing brain which affects motor control centers and causes alterations in growth, development, and overall health and function throughout the life span. Once established, the brain insult or structural malformation does not progress with time, but individuals with CP can develop secondary conditions which may interfere with important aspects of quality of life (eg, independence, activity, participation).[1] As a result, increasing clinical and research attention has begun to highlight the unique problems facing adolescents with CP as they transition to adulthood and those specific to aging in CP. Various secondary conditions may predispose young to middle-aged adults with CP to sustain morphologic and functional decline similar to that seen in late to middle-aged and older adults without CP.[2] Although the underlying mechanisms of this accelerated aging is not well-established, research has demonstrated that individuals with CP have significantly lower fitness[3] and are therefore at risk for functional and cardiometabolic health declines throughout adulthood.[4] Moreover, individuals with CP have diminished muscle size and strength[5] and lower bone mineral density (BMD),[6] collectively highlighting the risk for frailty in this population.

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Because of substantial deficits in overall lean tissue,[7-10] reliance on body mass index (BMI) in CP may disguise excess adiposity in visceral or other ectopic adipose depots (eg, liver, muscle, bone marrow).[11] There is some evidence to suggest greater general adiposity in children with CP[12]; however, this has yet to be well-studied in the adult CP population. In 2009, Johnson et al[13] provided some of the first evidence that young children with quadriplegic CP had significantly greater intermuscular adiposity than matched, typical neurodeveloping children and that the extent of infiltration was robustly associated with objectively measured physical inactivity. Early declines in function among individuals with CP may occur as a result of accelerated aging; however, it is equally plausible that the hallmark neuropathic symptoms (eg, chronic spasticity, fatigue, antagonist coactivation, low muscle tone) merely increase the likelihood of exaggerated sedentary behavior from early childhood.[2,14,15]

Along with the neuromuscular deficits and altered morphology in persons with CP, the increased sedentary lifestyles often found in this population have prompted a comparison model of disability with persons with spinal cord injury,[16] a population with significant muscle wasting, increased adipose tissue deposition, and elevated risk for cardiometabolic abnormalities.[17] Although a plausible comparison, virtually no research has addressed the long-term cardiometabolic consequences of CP or the interrelations between adipose tissue partitioning, altered muscle composition and atrophy, and BMD in this population. Therefore, the purposes of this study were to examine the differences in trunk adipose tissue distribution (ie, subcutaneous adipose tissue [SAT], visceral adipose tissue [VAT]), lumbar trabecular and cortical BMDs, and muscle attenuation (ie, an indicator of intermuscular adipose tissue) in adults with and without CP and between ambulatory and nonambulatory persons with CP, and to determine the associations between these morphologic characteristics after adjusting for age, sex, and body mass.

Method

Participants

Abdominal and thoracic computed tomography (CT) scans and patient records were obtained from a convenience sample of 41 adults (age range, 18−65y) with CP (age, 38.8±14.4y; body mass, 61.3±17.1kg) and a cohort of 311 neurotypical available clinical patients, matched for sex, age, and body mass. All CT scans took place in the same university health system between the years 2007 and 2013. Of the 41 subjects with CP, 10 subjects were not matchable because of very low body mass and therefore were included only as a comparison subset to the main CP cohort. The Gross Motor Function Classification System (GMFCS) was recorded for each patient with CP and ranged from levels I through V. The GMFCS assesses mobility status with a 5-level ordinal grading scale. Specifically, the GMFCS is used clinically to describe mobility status of individuals with CP on the basis of self-initiated movement and with emphasis on sitting, walking, and wheeled mobility. Distinctions between levels are also based on the need for assistive technology, including hand-held mobility devices (walkers, crutches, etc) and/or wheeled mobility. Individuals at level I can generally walk without significant restrictions, but they may experience limitations in advanced motor-related skills. Conversely, individuals at level V are usually very restricted in the ability to function, even with external assistive technology. Studies of the GMFCS to classify mobility status in the adult population with CP show it to be reliable (interclass correlation coefficient=.93), with excellent interrater reliability (quadratic κ value=.978).[18] All patients were examined by the same physician investigator to classify GMFCS level, which was obtained during chart reviews, and the breakdown for the different levels is as follows: GMFCS level I (n=4); GMFCS level II (n=5); GMFCS level III (n=9); GMFCS level IV (n=12); and GMFCS level V (n=11). The study was approved by the University of Michigan Institutional Review Board.

List of abbreviations:

BMD	**bone mineral density**
BMI	**body mass index**
CP	**cerebral palsy**
CT	**computed tomography**
GMFCS	**Gross Motor Function Classification System**
Hu	**Hounsfield units**
SAT	**subcutaneous adipose tissue**
VAT	**visceral adipose tissue**

Anatomic and morphomic data

Patient CT scans were processed and analyzed using a proprietary, semiautomated procedure developed using MATLAB software,[a] as previously described.[19,20] Trained CT processors were required to confirm the locations of vertebral levels, identify key anatomic landmarks for semiautomated visceral fascial determination, and draw contours of psoas major muscles at the L4 level. The algorithm applied these inputs to automatically generate anatomic and morphomic measurements. Trabecular bone density was measured as the mean density within a circle that was half the size of the vertebral body. Cortical bone density was measured as the mean of the level of half-maximum of the bone signal peak at every angle within a 60° wedge. Psoas major muscle attenuation was measured as the mean of voxel attenuation in Hounsfield units (Hu) within the psoas contours. The psoas major area was measured as the total area inside the psoas contours, and the lean psoas was measured as the area multiplied by normalized psoas density (mapping [−85,85] to [0,1]). The VAT area was measured as the total area inside the abdominal fascia meeting fat density thresholds, and the SAT area was measured as the total area between abdominal fascia and skin meeting fat density thresholds.

Statistical analysis

All statistical analyses were conducted using R statistical package[b] and SAS 9.3.[c] Anatomic and morphomic characteristics were examined between adults with CP and matched neurotypical adults and are provided as means and SDs. Unadjusted differences between groups were tested using 2 independent-samples *t* test. Adjusted differences in each characteristic were tested using multiple linear regression after creating a dummy variable for group and controlling for age, sex, and body mass. Among the adults with CP, we also examined correlation coefficients to assess the association between bone/muscle densities and age, body mass, VAT area, and SAT areas. Because of the concern of potential outliers in measuring densities, we report Spearman rank correlation coefficients (ρ), which are a nonparametric measure of statistical dependence. In using this method, we were able to also examine both linear and nonlinear associations.