Muscle Activation and Energy-Requirements for Varying Postures in Children and Adolescents with Cerebral Palsy

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Objective To determine energy expenditure and muscle activity among children and adolescents with cerebral palsy (CP), across several conditions that approximate sedentary behavior, and standing.

Study design Subjects with spastic CP (n = 19; 4-20 years of age; Gross Motor Function Classification System Expanded and Revised [GMFCS-E&R] levels I-V) participated in this cohort study. Energy-expenditure and muscle activity were measured during lying supine, sitting with support, sitting without support, and standing. Energy-expenditure was measured using indirect calorimetry and expressed in metabolic equivalents (METs). Muscle activation was recorded using surface electromyography. The recorded values were calculated for every child and then averaged per posture.

Results Mean energy expenditure was >1.5 METs during standing for all GMFCS-E&R levels. There was a nonsignificant trend for greater muscle activation for all postures with less support. Only for children classified at GMFCS-E&R level III did standing result in significantly greater muscle activation ($P < .05$) compared with rest.

Conclusions Across all GMFCS-E&R levels, children and adolescents with CP had elevated energy expenditure during standing that exceeded the sedentary threshold of 1.5 METs. Our findings suggest that changing a child's position to standing may contribute to the accumulation of light activity and reduction of long intervals of sedentary behavior. *(J Pediatr 2014;165:1011-6)*.

Prolonged periods of sedentary behavior have been associated with several metabolic risk factors and all-cause mortality, independent of participation in physical activity. This suggests that the protective effects of physical activity for health may be negated by prolonged bouts of sedentary behavior.[1-4] The study of sedentary behavior as a distinct concept, rather than the mere absence of moderate to vigorous physical activity (MVPA), is an important new area of research.[5] However, over the last decade, the definition of sedentary behavior has evolved, and consequently, distinguishing it from physical inactivity has been confusing.[6] Previously, being sedentary meant merely a lack of MVPA, regardless of the amount of habitual light and lifestyle activities. The currently accepted definition of sedentary behavior is "any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting or reclining posture."[6]

The MET is a physiological measure expressing the energy cost of activities, against a reference to the metabolic cost of rest (ie, 3.5 $mL \cdot kg^{-1}\ min^{-1}$ or 1 $kcal \cdot kg^{-1}\ h^{-1}$). Because of the lack of demand for recruitment of larger muscle groups, activities that require 1.0-1.5 METs are considered to be sedentary behaviors.[7] The second element defining sedentary behavior is related to posture and is based on previously published definitions that describe sedentary as muscular inactivity in sitting and reclining positions, instead of the absence of exercise per se.[8,9] Static standing should not be considered sedentary behavior because a large proportion of the body's muscles are activated to initiate and maintain standing, and there are generally some nondescript movements, such as shifting or fidgeting.[10,11] Recent findings demonstrate a strong negative association between time spent standing and the risk of mortality, supporting the notion that even light physical activity like standing is a potentially viable target for intervention.[12]

Despite the apparent advantages of this approach, any current definition of sedentary behavior for the general population may not be applicable to individuals with cerebral palsy (CP). The degree of neuromuscular deficits and mobility impairment is extremely variable among persons with CP, and there is likely heterogeneity in the energy expenditure and muscle activities between different levels of severity, even within similar postures.[13,14] Children and adolescents with CP engage in prolonged periods of sedentary time[15] and have diminished capacity to participate in moderate to vigorous activities.[16] In addition to the potential effectiveness of health-related physical activity in this

CP	Cerebral palsy
EMG	Electromyography
GMFCS-E&R	Gross Motor Function Classification System Expanded and Revised
METs	Metabolic equivalents
MVPA	Moderate to vigorous physical activity
RMS	Root mean square
VO_2	Oxygen uptake

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population, an intuitive first-step out of chronic, sedentary lifestyles may be to focus simply on fragmenting sedentary time. An evaluation of the energy consumption and muscle activity profiles of individuals with CP, during postures that are assumed to represent or approximate sedentary behavior (ie, sitting and standing), would provide valuable information about their actual physiologic demand. The purpose of this study was to determine the energy expenditure and muscle activation during lying, sitting, and standing, among individuals with CP with different levels of severity.

Methods

This exploratory study focused on children, adolescents, and young adults with CP, between the ages of 4 and 20 years, who were classified at Gross Motor Function Classification System Expanded and Revised (GMFCS-E&R) levels I-V. The Institutional Review Board of the University Medical Center Utrecht approved the study.

Based on clinical examinations, pediatric physiatrists who worked in a school for special education referred suitable subjects. A total of 19 children and youth with spastic CP (5 classified as having spastic unilateral CP, 14 as having spastic bilateral CP; 13 male, 6 female; age 4-20 years old) were recruited from the Mytylschool Ariane de Ranitz in Utrecht, and their parents provided informed consent for participation in this study. All the children received rehabilitation services in The Netherlands at the time of participation. Eight children classified at Gross Motor Function Classification System (GMFCS-E&R) levels I and II did not use any support for standing. The children classified at GMFCS-E&R levels III, IV, and V used walking or standing frames to keep an upright position. Subject characteristics are provided in Table I.

Prior to the energy expenditure and electromyography (EMG) measurements, each child was weighed on electronic scales (Seca, Hamburg, Germany). Height measurements were taken on the same visit. The EMG electrodes were, on the basis of palpation, placed on eight large muscle groups, including left and right quadriceps femoris; left and right biceps femoris; left and right gastrocnemius; and the left and right side of the erector spinae. A facemask, to measure oxygen consumption, was placed firmly around the mouth and nose.

After placement of the electrodes and the facemask, the child was asked to lie down in the supine position, on a comfortable treatment table. Each child's energy expenditure and muscle activity was measured during a standardized order of postures: (1) lying supine on a table; (2) sitting quietly on a chair with backrest; (3) sitting quietly on a chair without backrest; and (4) standing (with or without support). By using this order of testing, postures that require greater energy expenditures did not influence subsequent measures. Measurement of energy expenditure and muscle activity for each posture started when the energy expenditure was stable for 1 minute (ie, not more than 2 mL/kg/min oxygen uptake [VO_2] difference). Thereafter, the measurement was performed for 5 minutes during lying, and for 2 minutes during sitting (with and without support) and standing. As a requirement for accurate measurements, energy expenditures had to reach a steady state prior to termination of the test. The measurement time for sitting and standing was only 2 minutes, because for children classified at GMFCS-E&R levels III-V, sitting without support and standing is difficult. The facemask and EMG electrodes remained in place during the measurement session.

Measures

GMFCS-E&R. A pediatric physical therapist experienced in evaluating the GMFCS-E&R[17,18] used the translated Dutch version to classify children and adolescents with CP, according to their functional ability. The GMFCS-E&R assesses activity limitations for gross motor function with a 5-level ordinal grading scale. The GMFCS-E&R describes gross motor function of individuals with CP on the basis of self-initiated movement with an emphasis on sitting, walking, and wheeled mobility. Distinctions between levels are also based on the need for assistive technology, including handheld mobility devices (walkers, crutches, etc) or wheeled mobility. Individuals at "level I" can generally walk without significant restrictions, but may experience limitations in advanced motor-related skills. Individuals at "level V" are usually very restricted in their mobility, even with external assistive technology. Individuals at level III are able to ambulate with an assistive device such as crutches or a walker. Individuals at level IV are generally nonambulatory, although they sometimes can walk short distances with walkers.

Energy Expenditure. Indirect calorimetry was used to assess the metabolic demand of different postures, and

Table I. Subject characteristics

	GMFCS-E&R level I	GMFCS-E&R level II	GMFCS-E&R level III	GMFCS-E&R level IV	GMFCS-E&R level V
Number	4	4	6	3	2
Sex	4 male, 0 female	1 male, 3 female	4 male, 2 female	3 male, 0 female	1 male, 1 female
Age (y, mo)	12.0 ± 2.3	10.8 ± 6.8	14.3 ± 4.8	12.3 ± 5.7	10.5 ± 7.8
Weight (kg)	44.4 ± 13.3	34.3 ± 20.3	44.1 ± 13.3	45.7 ± 19.8	38.4 ± 30.5
Height (cm)	152.3 ± 13.6	132.0 ± 31.3	149.8 ± 16.4	142.7 ± 19.7	141.5 ± 36.1
BMI (kg/m^2)	18.7 ± 3.1	18.2 ± 3.9	19.1 ± 2.6	21.8 ± 5.9	17.0 ± 6.4
BMI percentile	56.3 ± 37.3	41.3 ± 45.6	40.8 ± 30.8	66.3 ± 53.1	29.5 ± 40.3
Type CP (uni/bi)	4/0	1/3	0/6	0/3	0/2

bi, bilateral; *BMI*, body mass index; *uni*, unilateral.
BMI percentile reference values were obtained from stature-for-age and weight-for-age data files from the Center and Disease Control, respectively.