Associations between Neuromuscular Function and Levels of Physical Activity Differ for Boys and Girls during Puberty

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Objective To compare the associations between neuromuscular performance and anthropometric characteristics with habitual levels of physical activity in boys and girls during the initial stages of puberty.

Study design In a cross-sectional study of 72 healthy children (39 boys and 33 girls) ranging in age from 8 to 14 years, sex differences in anthropometric and motor performance characteristics were compared at 3 Tanner stages (T1-T3). Outcome variables included dual-energy x-ray absorptiometry measurements of body composition, assessments of neuromuscular function, and levels of physical activity (steps/day) measured by accelerometry.

Results Physical activity was lower in girls than boys at T2 and T3, but there was no sex difference at T1. Physical activity increased with Tanner stage for boys but did not differ between Tanner stages in girls. Physical activity at each Tanner stage was strongly associated ($R^2 > 0.85$) with neuromuscular characteristics for both boys and girls, but percentage of body fat also was associated with physical activity for T3 girls.

Conclusions The attenuated gains in neuromuscular function experienced by girls in early stages of puberty were strongly associated with lower levels of physical activity, whereas the increase in physical activity exhibited by boys was mostly related to increases in the strength and endurance of leg muscles. Because sedentary activity is a known contributor to the development of obesity and type 2 diabetes in youth, this study helps to identify possible contributors to decreases in physical activity in young girls and provides potential targets for early intervention. *(J Pediatr 2013;163:349-54)*.

The decrease in physical activity level is a major contributor to the prevalence of childhood obesity.[1] This decrease appears to begin in early childhood (<12 years of age),[2] to be greater for girls than for boys,[2,3] and to be greatest between the ages of 13 and 18 years.[1,3] Because both obesity and decreased physical activity are associated with insulin resistance and type 2 diabetes, which are more common in female adolescents than in males,[4] it is critical to understand the factors that contribute to sex differences in changes in physical activity during puberty.

Although psychosocial factors appear to underlie the greater decrease in physical activity for adolescent girls (14-18 years), the timing of biological development moderates the chronological age at which physical activity begins to decline in children.[5] Biological factors such as heredity, sex, adiposity and nutritional status, health status, sexual maturity, proficiency in motor skills, and physical fitness can all influence levels of physical activity.[6] More mature girls at age 11 years, for example, exhibited greater decreases in physical activity by age 13 than girls who developed later.[7] Moreover, physical activity levels begin to decrease at about the same time and at a similar rate for boys and girls when habitual levels of physical activity are expressed relative to peak height velocity,[8] which is a measure of biological development and occurs at a later age in boys.[9] However, rates of change in neuromuscular function, which are also associated with the timing of peak height velocity, are much greater for boys than girls even when normalized to the timing of peak height velocity.[10] The potential contribution of attenuated increases in neuromuscular function to the greater decreases in physical activity observed in girls during pubertal development remains unknown.

Because changes in lean tissue mass and skeletal dimensions also occur at different chronological ages for boys and girls during puberty,[9,10] the objective of the current study was to compare the associations between neuromuscular performance and anthropometric characteristics with habitual levels of physical activity in prepubertal boys and girls and during the initial stages of puberty. The hypothesis was that lower levels of physical activity exhibited by girls during early puberty would be associated with attenuated neuromuscular function but not with larger skeletal dimensions.

CTRC	Clinical Translational Research Center
MVC	Maximal voluntary contractions
T1	Tanner stage 1
T2	Tanner stage 2
T3	Tanner stage 3

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Methods

The study was performed at the University of Colorado Boulder after approval by the Institutional Review Board. Informed consent was obtained from one parent, and informed assent was obtained from the child. The protocol involved 3 experimental sessions: 1 at the Clinical Translational Research Center (CTRC) and 2 at the Neurophysiology of Movement Laboratory.

The study population comprised 72 healthy children (39 boys and 33 girls), ranging in age from 8 to 14 years. The children were recruited from schools in the Boulder and Denver communities and matched the ethnic distribution. All children were free of neurologic diseases, advanced chronic disease states, or any other physical condition that would obviously impair their ability to perform tests of motor function. Physical examinations were performed by CTRC physicians who were trained by a pediatric endocrinologist, and children were classified into Tanner stage 1 (T1, prepubertal), Tanner stage 2 (T2), or Tanner stage 3 (T3) according to the criteria defined by Marshall and Tanner.[6] The study enrolled 17 boys and 13 girls at T1, 10 boys and 10 girls at T2, and 12 boys and 10 girls at T3.

Body composition was characterized by height, mass, and body mass index, and dual-energy x-ray absorptiometry (Lunar Prodigy Pro; GE Healthcare, Madision, Wisconsin) provided estimates of total fat mass, lean mass, and bone mineral density and content. Dual-energy x-ray absorptiometry also was used to measure selected skeletal dimensions: lengths of the tibia, femur, humerus, and forearm, and biiliac width. In the same session at the CTRC, each child was given an ActiGraph device (ActiGraph, Pensacola, Florida) and told that it would measure the amount of physical activity.[11] Children were instructed to wear the device on the right hip during waking hours for 7 days and to remove it only when going to bed at night and when performing water-based activities, such as showering, bathing, or swimming. Each ActiGraph was set to record data in 60-second sampling intervals. Data recorded on the first and last days were not included in the analysis. Previous work has shown 4 four days of ActiGraph data provide reliable estimates of usual physical activity in youth.[12]

Motor performance was assessed in the subsequent 2 sessions. The upper and lower limbs were tested in separate, randomized sessions with measurements of muscle strength, muscle endurance, and motor function that have been used in previous studies on children.[13-19] Muscle strength was quantified as the peak force achieved during maximal voluntary contractions (MVC) with the knee extensors and flexors of the left leg, the elbow extensors and flexors of the left arm, and handgrip with the left and right hands.[13,14] MVC force for the extensors and flexors was measured with a force transducer attached either at the level of the ankle or wrist, respectively. Handgrip strength was measured with a hand-held dynamometer. Subjects increased muscle force gradually from rest to maximum and sustained the contraction for ~3 seconds during each MVC. Participants completed no more than 5 MVC trials, with at least 60 seconds of rest between trials. The peak value during the MVC trials was taken as the MVC force provided it was within 5% of the value recorded in another trial. Handgrip strength was characterized as the greatest force from three trials for each hand.

Muscle endurance was quantified as the endurance time for a sustained isometric contraction. The task for the lower limbs was a wall squat.[15] Each child was instructed to maintain the knee joint angle at 90° with the back pressed flat against a wall and were given verbal encouragement to hold the position for as long as possible. The endurance for the upper limbs involved supporting a submaximal load with the elbow flexors for as long as possible. Knee or elbow joint angle, respectively, was measured with an electrogoniometer and displayed on a monitor using a customized Labview program (version 8.2, National Instruments, Austin, Texas). Both tasks were terminated when the joint angle deviated by 10° from the target angle.

Motor function was assessed with a chair-rise test[16] for the lower limb and the grooved pegboard test[17] for the upper limb. The chair-rise test required the children to stand up and sit back down from a chair 5 times as quickly as possible. The time taken to complete the 5 repetitions was recorded with a stopwatch. Two trials were conducted, and the fastest time was included in the analysis. The grooved pegboard test involved placing small metal pegs into 25 holes arranged in 5 rows of 5 holes. The pegs were inserted into the rows of holes sequentially beginning in the top left corner for the left hand and the top right corner for the right hand. Any peg could fit into any hole, but only when the orientation of its key-hole shape was aligned with that of hole. The orientation of the 25 holes varied across the board. All children completed 2 trials with each hand and the fastest time for each hand was used in the analysis.

Statistical Analyses

ANOVA were used to compare the effects of sex and Tanner stage with anthropometric characteristics, neuromuscular function, and physical activity variables. Paired t tests (independent and dependent) with Bonferroni corrections were used as post-hoc analyses to compare differences between pairs of means when appropriate. Stepwise, linear regression analysis using forward selection was performed to examine the associations between potential explanatory variables and the level of physical activity (steps/day). The coefficient of determination (R^2 or adjusted R^2 where appropriate) was used to evaluate the fit of our models and guide the stepwise selection procedure.

The significance level for all statistical tests was set at $P < .05$. Data are reported as means ± SD within tables. All regression analyses, including the stepwise procedure, were performed with SPSS software (version 17.0; SPSS Inc, Chicago, Illinois).

Results

The physical characteristics of the participants and ActiGraph data are presented in Table I. Sex × Tanner stage