Associations of Adiposity and Aerobic Fitness with Executive Function and Math Performance in Danish Adolescents

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Objective To examine the associations of adiposity and aerobic fitness with executive function and math performance in Danish adolescents.

Study design Cross-sectional analyses were conducted with data on 525 adolescents attending sixth and seventh grades from 14 schools in the 5 main regions of Denmark. A modified Eriksen flanker task was used to assess inhibitory control, a key aspect of executive function. Academic performance was assessed by a customized math test. Aerobic fitness was assessed by an intermittent shuttle-run test (Andersen test).

Results Body mass index (BMI) was negatively associated with accuracy on incongruent trials during the flanker task (P = .005). A higher BMI was associated with a larger accuracy interference score (P = .01). Similarly, waist circumference (WC) was negatively associated with accuracy on incongruent trials (P = .008). A higher WC was associated with a larger reaction time (RT) interference score (P = .02) and accuracy interference score (P = .009). Higher aerobic fitness was associated with a faster RT on congruent trials (P = .009) and incongruent trials (P = .003). Higher aerobic fitness was associated with a smaller RT interference score (P = .04). Aerobic fitness was positively associated with math score (P < .001). BMI and WC were not associated with math score (P > .05).

Conclusions These results suggest that aerobic fitness is positively associated with both inhibitory control and math performance in adolescents. Adiposity is negatively associated with inhibitory control in adolescents. Adiposity is not associated with math performance. *(J Pediatr 2015;167:810-5)*.

Childhood obesity is negatively correlated with various domains of cognitive function.[1-3] Childhood obesity has more frequently been found to be associated with poorer executive function compared with other domains of cognitive function.[1] By contrast, Gunstad et al[4] found that elevated body mass index (BMI) was not associated with several domains of cognitive function including executive function in children and adolescents. Executive function, also called cognitive control, refers to a family of higher-order, self-regulatory cognitive processes that aid in the monitoring and control of thought and action.[5] Inhibitory control, working memory, and cognitive flexibility are the 3 core executive functions.[6,7] Evidence has shown that executive function is important for school readiness and academic performance in school years.[7] For example, inhibitory control, working memory, and cognitive flexibility were positively correlated with math ability in preadolescents.[8] However, findings on the association between adiposity and academic performance have been inconsistent. Some studies found no association between adiposity and academic performance,[9-11] whereas others observed a negative association.[12,13]

Previous studies have shown that preadolescents with superior aerobic fitness demonstrated better executive function than their low-fit counterparts.[14-16] Scudder et al[17] reported that a field-based measure of aerobic fitness was positively associated with executive function measured by a modified flanker task and a spatial n-back task in school children aged 6-9 years. The purpose of the study was to examine the association of adiposity and aerobic fitness with executive function and math performance in Danish adolescents.

Methods

This investigation analyzed the baseline data from the Learning, Cognition and Motion (LCoMotion) study, a multicomponent cluster randomized school-based intervention study aimed at increasing learning and cognitive function.[18] In total, 14 schools from the 5 main regions of Denmark were recruited for the study. All students (N = 869) in sixth- and seventh-grade classes in these schools were invited to participate in the LCoMotion; 87% of the parents provided consent for their child to participate in the study (N = 759). In total, 525 adolescents with relevant

BMI	Body mass index
ICC	Intraclass correlation coefficient
RT	Reaction time
WC	Waist circumference

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data were included in this study. The study was approved by the ethics committee of the region of Southern Denmark. Baseline measurements were conducted by trained research personnel in November and December of 2013. The study protocol is described in detail elsewhere.[18]

Body height was measured to the nearest 0.5 cm using a Harpenden stadiometer (Harpenden, West Sussex, United Kingdom). Body weight was measured to the nearest 0.1 kg using an electronic scale (BWB-800; Tanita, Tokyo, Japan). BMI was calculated as weight (kg) divided by height (m) squared. Waist circumference (WC) was measured to the nearest 0.5 cm with an anthropometric tape at the level of the umbilicus. Participants self-reported their sexual maturation using the Tanner scale.[19] For this study, girls were staged according to breast development. Boys were staged according to the development of pubic hair.

Aerobic fitness was indirectly assessed with the Andersen intermittent shuttle-run test.[20,21] Two parallel lines 20 m apart were marked on the floor. Participants were instructed to run from 1 line to the other. They had to touch the line with 1 hand, turn around, and run back. Music signalled 15 seconds of running and 15 seconds of rest. Participants had to stop immediately at the signal. This procedure was followed for 10 minutes, which gave a running time of 5 minutes in total. Participants were told to run as fast as they could in order to cover the most possible distance. This distance in meters was the test outcome, which has been validated against direct measure of maximal oxygen uptake (VO_{2max}).[20,21]

A modified Eriksen flanker task was used to assess inhibitory control.[22] The computer-based task consisted of congruent and incongruent trials. Congruent trials consisted of an array of 5 horizontal arrows facing the same direction (eg, <<<<< or >>>>>) and incongruent trials consisted of the 4 flanking arrows facing the opposite direction to that of the central arrow (eg, <<><< or >><>>). For both congruent and incongruent trials, participants were instructed to press a key corresponding to the direction of the centrally presented target arrow. Participants were instructed to respond as quickly and accurately as possible. The congruent and incongruent trials were randomly introduced. First, participants completed a practice block of 20 trials to train them in what was expected and to identify any problems they had in understanding and performing the test. If this test was not satisfactory, another practice block was completed, and this was repeated until the tester was confident that the participant understood the task correctly. Subsequently, participants completed 2 blocks of 150 trials (75 trials in each block). Stimuli presented for 120 milliseconds (ms) with a response window of 1350 ms. A random interstimulus interval of 1250-1550 ms separated each trial and a break of 30 seconds separated each block. The entire task was completed within 8 minutes. The outcomes for the test were reaction time (RT) of correct responses (ms) and accuracy (percentage of correct response). Interference scores were derived by calculating the difference in performance between the 2 conditions for both RT (incongruent-congruent) and accuracy (congruent-incongruent).[23]

Academic skills were assessed by a math test consisting of 50 questions of varying difficulty matching the requirements of the sixth- and seventh-grade curriculum of Danish schools, respectively. Participants were allowed 45 minutes to complete the test. The math test was scored by the research staff. The math test was validated against a standardized math test often used by the Danish Ministry of Education.[18] A correlation coefficient of 0.87 ($P < .001$) was found between the standardized and the applied test.[18]

Information on ethnicity, highest educational level of parents, and child's participation in special education was obtained by questionnaires. Mother's highest educational level was used as an indicator of parental social economic status. The education level was collapsed into 3 categories: (1) basic school and high school; (2) vocational programs; and (3) bachelor's degree or higher. Ethnicity was categorized into Danish, non-Danish European, and others.

Statistical Analyses

Descriptive characteristics were summarized by sex. For continuous variables, the differences were evaluated using an unpaired t test. Categorical variables were assessed using χ^2 test. The correlation between the performance on the flanker task and math performance were assessed using Pearson correlation. Owing to the cluster sampling procedure, we first estimated the intraclass correlation coefficient (ICC) of clustering within classes. The ICCs for the performance on the flanker task were very low (<0.04). Therefore, the associations of aerobic fitness and adiposity with inhibitory control were analyzed with linear regression modeling. The ICC for math score was 0.165, which indicated that 16.5% of the variance was explained by the clustering of students within classes. Therefore, linear mixed effect modeling was conducted to assess the association of aerobic fitness and adiposity with math scores in order to adjust for the effects of clustering within classes. Standardized correlation coefficients were reported. Of the 525 adolescents, 493 adolescents were included in the analyses of inhibitory control. Five adolescents had missing data on the flanker task because of their absence from school. Twenty-seven adolescents were excluded from analysis because of their accuracy lower than 50% (below chance) on either congruent or incongruent trials during the flanker task. Five hundred eighteen adolescents were included in the analyses of math performance. Seven adolescents had missing data on the math test because of their absence from school. All statistical analyses were conducted with Stata 12 for Windows (StataCorp LP, College Station, Texas), and the level of significance was set at P value of <.05 (2-sided).

Results

Table I presents descriptive characteristics of the participants stratified by sex. Boys were older, had a larger WC, and also greater aerobic fitness than girls (all $P < .05$). No differences were observed in body height, body weight, BMI, weight