# Physical Activity Is Associated with Attention Capacity in Adolescents

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**Objective** To assess the relationships among physical activity, measured objectively, and attention capacity in European adolescents.

**Study design** The study included 273 adolescents, aged 12.5-17.5 years, who participated in the Healthy Lifestyle in Europe by Nutrition in Adolescence Study. Participants wore a uniaxial accelerometer for 7 days to measure physical activity. The d2 Test of Attention was administered to assess attention capacity. Multivariate analyses were used to study the association of attention capacity with each measure of physical activity. Receiver operating characteristic analysis was performed to determine thresholds that best discriminate between low and good attention capacity.

**Results** After controlling for potential confounding variables (age, sex, body mass index, parental educational level, fat mass, aerobic fitness, and center), adolescents' attention capacity test performances were significantly and positively associated with longer time spent in moderate or moderate-to-vigorous physical activity (MVPA) in free-living conditions ($P < .05$). Receiver operating characteristic curve analyses revealed that the physical activity thresholds that best discriminated between low/good attention capacities were $\geq$41 min·day$^{-1}$ for moderate, $\geq$12 min·day$^{-1}$ for vigorous, and $\geq$58 min·day$^{-1}$ for MVPA.

**Conclusion** These findings suggest that promoting MVPA may be have a beneficial effect on attention capacity, an important component of cognition, in adolescents. *(J Pediatr 2016;168:126-31)*.

Physical activity is an important determinant of health throughout the lifespan. Engaging in regular moderate-to-vigorous physical activity (MVPA) has important health benefits, especially in the treatment of metabolic syndrome-related disorders such as obesity, heart and pulmonary diseases, bone and joint diseases, cancer, depression, asthma, and in cognitive function.[1-3]

The 2 important measures of cognition in children and adolescents are attention and concentration because they are indispensable elements in comprehension and learning processes.[4-6] Attention is the behavioral and cognitive process of selectively concentrating on one aspect of the environment while ignoring other things.[5,6] Sibley and Etnier[2] performed a meta-analysis on physical activity and cognition in children and concluded that there is a significant positive relationship between physical activity and cognitive function in children; however, their analysis included only studies conducted to investigate the effects of exercise type on cognitive function. Moreover, in this meta-analysis, 8 categories of cognitive assessment tools were used: perceptual skills, IQ, achievement, verbal tests, math tests, memory, developmental level, and academic readiness. Although there could be overlap between IQ testing and some aspect of attention, no specific study assessing attention capacity was included in the meta-analysis. Some interventional studies showed that the type,[4,7] duration,[8,9] or intensity of physical activity positively influenced cognitive functions.[10] Indeed, studies have suggested that short bouts of exercise on coordinative skills or a single and acute bouts of MVPA might have an impact on attention capacity in adolescents.[7-9,11-13] All of these studies examined the improvement of the attention ability after an acute challenge intervention.[7-9,11-13] However, to our knowledge, no previous study has examined baseline attention capacity with respect to adolescent physical activity patterns.

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| AUC | Area under the receiver operating characteristic curve |
| BMI | Body mass index |
| d2T | d2 Test of Attention |
| HELENA | Healthy Lifestyle in Europe by Nutrition in Adolescence |
| ISCED | International Standard Classification of Education |
| MVPA | Moderate-to-vigorous physical activity |
| ROC | Receiver operating characteristic |

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The primary aim of the present study was to investigate the relationship of physical activity, measured objectively, with the attention capacity in European adolescents. The secondary aim was to establish the optimal physical activity intensity cutoff that best discriminates between low and good attention capacities.

## Methods

This is an ancillary study of the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) Study (www.helenastudy.com) performed in European adolescents (2006-2007). The aim of the HELENA Study was to obtain a broad range of standardized, reliable, and comparable nutrition- and health-related data from a random sample of European adolescents aged 12.5-17.5 years. The random selection of schools and classes was performed centrally (by Ghent University) for all cities except Pecs and Athens, where schools were selected locally owing to local administrative constraints. Details of the selection criteria for schools and classes were reported previously.[14] The inclusion criteria were male or female aged 12.5-17.5 years, schooling in 1 of the participating classes, consent form signed by parent and/or legal guardian, and no concurrent participation in another similar study. Each participating center was asked to include approximately 150 male and female adolescents per age stratum (ie, aged 12.5-14, 14-15, 15-16, and 16-17.5 years).

A total of 3528 adolescents (1844 girls and 1684 boys) meeting the inclusion criteria completed all examinations. A detailed description of the HELENA Study methodology and sampling is available elsewhere.[15,16] For the purpose of the present study, all participants with valid data on physical activity, anthropometric characteristics, aerobic fitness, and attention ability were included in the analysis (n = 273) (**Figure 1**; available at www.jpeds.com). Data were obtained from 6 countries: France (Lille), Spain (Zaragoza), Austria (Vienna), Germany (Dortmund), Hungary (Pecs), and Greece (Athens).

The aims and objectives were explained in detail, and written consent was obtained from each participant and a parent or legal guardian. The local Ethics Committee for each participating institution approved the HELENA Study, and all procedures were performed in accordance with the ethical standards of the Declaration of Helsinki (as revised in 2008) and European Good Clinical Practice Guidelines.[17]

Weight was measured with the subject wearing light clothing, without shoes, to the nearest 0.1 kg using an electronic scale (model 871; Seca, Hamburg, Germany). Height was measured without shoes to the nearest 0.1 cm using a telescopic measuring instrument (model 225; Seca). Body mass index (BMI) was calculated as weight (kg)/height$^2$ ($m^2$). Nutritional status was assessed based on the International Obesity Task Force scale.[18]

Total fat and fat-free mass were assessed using bioelectrical impedance analysis (model BIA101 body composition analyzer; Akern, Pontassieve, Italy). After a 5-minute rest, the subject was placed supine with the arms and legs in abduction between 30 and 40 degrees from the trunk. Electrode tape, conductivity gel, and current electrodes were placed on the dorsal surfaces of the right hand and foot at the distal metacarpals and metatarsals, respectively.[19]

Parental educational level was classified into 1 of 4 categories using a specific questionnaire, adapted from the International Standard Classification of Education (ISCED) (http://www.uis.unesco.org/Library/Documents/isced97-en.pdf): 1, primary education (level 0 and 1 in the ISCED classification); 2, lower secondary (level 2 in the ISCED classification); 3, higher secondary (level 3 and 4 in the ISCED classification); or 4, tertiary (level 5 and 6 in the ISCED classification).

Attention capacity was assessed using the d2 Test of Attention (d2T).[20] Developed to measure sustained attention and concentration under stress induced by a completion time, the d2T was used because it is low cost, easily and rapidly administered, and enables testing of large numbers of people simultaneously. The d2T assesses performance in terms of visual perceptual speed and concentrative capacities by assessing an individual's ability to selectively, quickly, and accurately focus on certain relevant aspects in a task while ignoring other irrelevant aspects. This test reflects 3 components of attentional/concentration behavior: speed/velocity, based on quantity of work performed in a given period; concentration, based on quality of work; and performance quality, based on the relationship between speed/velocity and concentration. The d2T is a paper-and-pencil letter-cancellation test comprising 14 different lines, each containing 47 randomly mixed letters ("p" and "d"), for a total of 658 letters. The letters "p" and "d" appear with 1 or 2 dashes above or below each letter. The test subject has to carefully check whether each letter "d" has 2 dashes either above or below it, at a rate of 20 seconds per line. The complete duration of the test is 4 minutes and 30 seconds. The d2T was administered in a classroom under the supervision of an HELENA fieldworker during the morning. All tests were performed before the physical activity assessment. A low error rate indicates high-quality performance. The documented reliability of the d2T ranges from 0.95 to 0.98, with a validity coefficient of 0.47.[20]

Attention capacity was calculated using the following formula: number of correct guesses (ie, number of correct relevant elements) − commissions (ie, number of irrelevant elements marked). Percentiles of attention capacity were determined using the norms given in the test manual, according to sex and age from raw data. Percentiles of attention capacity could be divided into 2 categories: low attention capacity (<25th percentile) and normal to high attention capacity (≥25th-75th percentile).

A physical activity monitor (model GT1M; ActiGraph, Pensacola, Florida) was used to assess physical activity in free-living conditions.[21] This small, lightweight uniaxial accelerometer has been validated against oxygen consumption and heart rate measurements for assessing physical activity.[22] Its inter-instrument reliability is high for both sedentary and vigorous activities. The device's epoch interval was set at 15 seconds. The subject wore the accelerometer on the lower back with an elastic belt and adjustable buckle, and