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Are Early Physical Activity and Sedentary Behaviors Related to Working Memory at 7 and 14 Years of Age?

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Objective To evaluate the role of extracurricular physical activity and sedentary behavior at preschool and primary school age on working memory at primary school age and adolescence, respectively.

Study design This prospective study was based on a birth cohort across 4 Spanish regions. In the 3 younger subcohorts (n = 1093), parents reported lifestyle habits of child at age 4 years of age on a questionnaire, and children performed a computerized working memory task at 7 years of age. In the older subcohort (n = 307), the questionnaire was completed at 6 years of age and working memory was tested at 14 years of age. Adjusted regression models were developed to investigate the associations between lifestyle habits and working memory.

Results Low extracurricular physical activity levels at 4 years of age were associated with a nonsignificant 0.95% (95% CI –2.81 to 0.92) reduction of correct responses in the working memory task at age 7 years of age. Low extracurricular physical activity levels at 6 years of age were associated with a 4.22% (95% CI –8.05 to –0.39) reduction of correct responses at age 14 years. Television watching was not associated with working memory. Other sedentary behaviors at 6 year of age were associated with a 5.07% (95% CI –9.68 to –0.46) reduction of correct responses in boys at 14 years of age.

Conclusion Low extracurricular physical activity levels at preschool and primary school ages were associated with poorer working memory performance at primary school age and adolescence, respectively. High sedentary behavior levels at primary school age were related negatively to working memory in adolescent boys. *(J Pediatr 2017;■■:■■-■■).*

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Healthy lifestyle habits, such as high levels of physical activity and low levels of sedentary behavior, are considered as a fundamental prerequisite for the development of basic cognitive, motor, and social skills in children.[1] These lifestyle habits may also influence the development of higher order cognitive processes, known as executive functions.[2] One of the most relevant executive functions for learning is working memory, the ability to keep information "online" for a short period of time for cognitive processing. Working memory develops significantly across childhood and adolescence, which has important implications for academic achievement.[3] The association between physical activity and working memory in children has been explored in only a few studies,[4-8] which were generally supportive for positive associations. Regarding sedentary behavior, although weak negative associations have been observed between television (TV) watching and working memory,[9] contradictory associations have been reported for video game playing.[10,11] To our knowledge, prior studies have not explored the association between other sedentary behaviors and working memory. However, objectively measured sedentary time has been associated positively with sustained attention,[10] which could have an impact on working memory performance.

The scarcity of available studies on the associations between these lifestyle habits and working memory in children, as well as the inconsistency of their results,

TV	Television

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warrants further investigation of these associations. Moreover, the cross-sectional design of most of these studies limits their ability to establish the causal nature of such associations.[5-7,10] In addition, it would be interesting to study these associations across different developmental periods, because both the type of activities and cognitive development varies across ages.[2,12] We aimed to investigate the association between physical activity and sedentary behavior at preschool age and working memory at primary school age, and the association between physical activity and sedentary behavior at primary school age and working memory at adolescence.

Methods

This study was conducted in the context of the population-based INMA (Infancia y Medio Ambiente [Environment and Childhood]) birth cohort across 4 Spanish regions: Menorca (n = 530), Valencia (n = 855), Sabadell in Catalonia (n = 657), and Gipuzkoa in Basque Country (n = 638).[13] In Menorca (the older subcohort), women attending antenatal care were recruited over a 12-month period starting in mid 1997, whereas in Valencia, Sabadell, and Gipuzkoa (the younger subcohorts), recruitment took place between 2003 and 2008. In total, 1093 children in the younger subcohorts and 307 in the older subcohort who had data available on both lifestyle habits and cognitive function were included in the current study (**Figure**). All participants gave written informed consent before enrollment in the subcohorts. Each subcohort obtained study approval from the ethics committee in its corresponding region.

Data on extracurricular physical activity and sedentary behavior were collected through questionnaires administered to parents (mainly the mother) when children were 4 years of age in the younger subcohorts, and when children were 6 years of age in the older subcohort (**Appendix**; available at www.jpeds.com). We focused on extracurricular physical activity because it is more variable among children than school physical activity, which is highly standardized across Spain. Parents answered the following question regarding physical activity, "During a typical week, how long does your child perform extracurricular exercise in each day, eg, dance/swimming lessons, or just playing, running, cycling, skating, swimming, etc.?" In Menorca, the question did not include outdoor playing, walking, and cycling, because structured physical activity is more beneficial for cognitive development than unstructured physical activity at this age.[2] Parents were able to specify more than 1 activity in Gipuzkoa and Sabadell.

In all regions, parents answered the following question regarding TV viewing: "How many hours does your child watch TV per week?" Parents reported other sedentary behaviors through the question, "Outside school, how long does your child dedicate to games or sedentary activities (eg, puzzles, books, dolls, homework, computer/video games)?" Because the questions were not identical in all the regions, we harmonized the answers a posteriori. We transformed categorical variables to continuous variables as minutes and hours per day (**Appendix**).

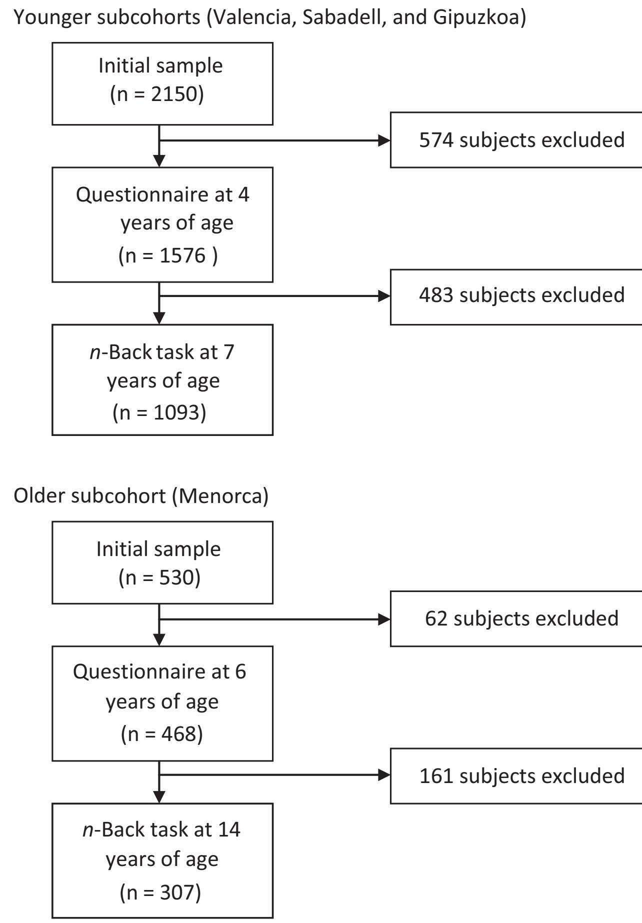

Figure. Flowchart of the study population.

These continuous variables were then converted to hours per week. In Menorca, we excluded TV watching from sedentary behavior by subtracting the value obtained in the specific TV watching question.

We tested working memory using computerized *n*-back task[14] at 7 years of age in the younger subcohorts and at 14 years of age in the older subcohort. This instrument has been validated in the Spanish general population.[15] The duration of the sessions was 25 minutes. Briefly, in the *n*-back task, participants have a sequence of stimuli on the computer screen, one at a time, and they have to respond (hit a button) when the current stimulus matches the one presented *n* steps before. The specific visual *n*-back task used consisted of a series of numbers, and 3 levels of difficulty or loads (1-, 2-, and 3-back). Stimuli were presented in a fixed central location on a white background for a 1500-ms duration with a 1000-ms interstimulus interval. Participants completed 3 blocks (1-, 2-, and 3-back) with each block being consisted of 25 trials. Targets never appeared in the first 3 trials of each block and 33% of stimuli of the following trials were targets. In the present study, we used 2-back as the main outcome, because it showed better properties than the 1- and 3-back tasks (eg, clear age-dependent slope and little learning effect) in a previous study.[16] Addi-

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