ASSOCIATION BETWEEN CARDIORESPIRATORY RESISTANCE AND INTELLECTUAL MATURITY IN PRIMARY SCHOOL CHILDREN: EDUCATIONAL IMPLICATIONS

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Abstract. Objective. This study analysed the relation between 10-12-year-old student’s cardiorespiratory resistance and their intellectual maturity as indicator to improve the academic performance. Method. Data were collected from primary education schools in Spain. A total of 150 children in 5th and 6th grades (age = 10.72 ± 1.25 years of age) participated. The Leger test measured cardiorespiratory fitness, the Goodenough-Harris Drawing test assessed intellectual maturity and the school grades the academic performance. Results. Significant differences were found between the genders; boys showed greater cardiorespiratory endurance. However, there were no significant genders differences in mental age. Children with better aerobic endurance physical scores scored better on the Goodenough-Harris Drawing test. In turn, intellectual maturity turned out to be a solid indicator of academic performance. Conclusions. There is a relationship between intellectual maturity and cardiorespiratory endurance in children in the third cycle of primary education, which is relevant to health and academic performance.

Key words: Cognitive development, academic performance, educational achievement physical conditioning, health education, primary education
ASOCIACIÓN ENTRE RESISTENCIA CARDIORRESPIRATORIA Y MADUREZ INTELECTUAL EN NIÑOS DE ESCUELA PRIMARIA: IMPLICACIONES EDUCATIVAS

Resumen. Objetivo. Este estudio analizó la relación entre la resistencia cardiorrespiratoria de estudiantes de 10 a 12 años y su madurez intelectual como indicador para mejorar el rendimiento académico. Método. Los datos se recogieron de centros de Educación Primaria de España. Participaron un total de 150 niños de 5° y 6° grado (edad = 10,72 ± 1,25 años). La prueba de Leger midió la aptitud cardiorrespiratoria, la prueba de dibujo de Goodenough-Harris evaluó la madurez intelectual y las calificaciones escolares el rendimiento académico. Resultados. Se encontraron diferencias significativas entre los géneros; los chicos mostraron mayor resistencia cardiorrespiratoria. Sin embargo, no hubo diferencias significativas de género en la edad mental. Los niños con mejores puntuaciones físicas de resistencia aeróbica obtuvieron mejores resultados en la prueba de dibujo de Goodenough-Harris. A su vez, la madurez intelectual resultó ser un indicador sólido del rendimiento académico. Conclusiones. Existe una relación entre la madurez intelectual y la resistencia cardiorrespiratoria en niños del tercer ciclo de Educación Primaria, lo cual es relevante para la salud y el rendimiento académico.

Palabras clave: Desarrollo cognitivo, rendimiento académico, logro educativo, acondicionamiento físico, educación para la salud, educación primaria.

Introduction

Several investigations have investigated the importance of physical activity in children’s health (Boreham & Riddoch, 2001; Janssen et al., 2010). There are numerous biomarkers that determine people’s health from a very young age, being physical condition one of them (Ortega, Ruiz, Castillo & Sjöström, 2008). In turn, it is possible to find a connection between body growth, physical condition (Ortega et al., 2011) and cognition (Heinonen et al., 2008). Similarly, there is a close association between motor and cognitive development, which takes place in the cerebellum and prefrontal cortex.

Children who are in good physical shape have greater cortical activation which in turn is reflected in better cognitive performance (Tomporowski, Davis, Miller & Naglieri, 2008). Haapala et al. (2015) and Aberg et al. (2009) showed that motor skills and cardiorespiratory resistance play an important role in cognitive development during childhood and young adulthood. Therefore, increasing physical fitness levels is beneficial for cognition during preadolescent development (Latorre Román, García Pinillos, Pantoja Vallejo, & Berrios Aguayo, 2017; Berrios Aguayo, Pantoja Vallejo, Latorre Román, 2019).

The analysis of children's drawings can be an important indicator of some cognitive aspects such as intellectual maturity (Pérez Testor & Pérez Testor, 2000; Loxton, Mostert, & Moffatt, 2006; Soto, Mendoza y Ramírez, 2009) or even as intelligence indicator (Mamani Ortiz, Choque Ontiveros, & Rojas Salazar, 2014). Furthermore, studying the progression of the drawings that children make over a period of time can show the level of intellectual development (Thomas & Jolley, 1998). In several investigations, children's drawings have been used to analyse cognitive and motor skills (Hasab Allah, El Adawy, Moustafa & Ali, 2012; Imuta et al., 2013; Latorre-Román, Mora-López & García-Pinillos, 2016; Soto et al., 2009). Although the association between physical fitness and cognitive functions has been
investigated in various studies (Ellemberg & St-Louis-Deschênes, 2010; Gallotta et al., 2015; Janssen et al., 2014), the relationship between physical condition, mainly cardiorespiratory resistance, and intellectual maturity is unclear.

The chronological age and its relationship with the academic performance has been widely studied (Ardoy et al., 2014; Abel et al., 2016; Vergel-Ortega, Martínez-Lozano, Zafra-Tristancho, & Zafra-Tristancho, 2016). Nevertheless, the association between intellectual maturity and school performance has not got the enough attention, being it really relevant for educational implication.

Taking into account the above information, we propose the following hypothesis: children with greater cardiorespiratory resistance have an older mental age as well as a better academic performance. Therefore, the purpose of this study is to analyse the relationship between mental age and cardiorespiratory resistance in children 10-12 years old which knowledge could be useful to improve the academic performance.

Method

Participants
A total of 150 children 10-12 years old (age = 10.72 ± 1.25 years of age) participated. Demographic characteristics revealed that 81 children were male and 69 were female, and they were selected from two primary schools in southern Spain, one public and one private. Every students of those courses participated in this study except a total of five students with intellectual or physical disabilities such as a wheelchair user or an autistic person. The parents were given an explicit verbal description of the nature and purpose of the research to be carried out and consequently their informed consent was obtained. The study was conducted in compliance with the standards of the Declaration of Helsinki (2013). The study was approved by the Bioethics Committee of the University of Jaen.

Materials and testing

Anthropometric variables
Height (cm) was measured with a stadiometer (Seca 222, Hamburg, Germany) and weight with a weighing scale (Seca 899, Hamburg, Germany). Body mass index (BMI) was calculated by dividing weight (in kilograms) by height$^2$ (in metres).

Physical variables
Cardiorespiratory endurance was assessed using the Leger test (Leger, Mercier, Gadouryl and Lambert, 1988). In this test, the students start walking and finish running, moving from one point to another located 20 metres away and making a change in direction to the rhythm indicated by a sound signal that is accelerated progressively. The test is stopped when the participant cannot maintain the race pace, registering the last period of the test in which the individual was.

The maximum oxygen consumption (VO$_2$ max.) was calculated taking into account the speed that the participant reached using the following equation: VO$_2$ max. = (31.025) + (3.238 * X) - (3.248 * A) + (0.1536 * A * X), X = speed, A = age (Leger et al., 1988). It is another appropriate indicator of cardiorespiratory endurance (Kabiri, Mitchell, Brewer, & Ortiz, 2017).
The reliability and validity of Leger test for determining the VO2 max in children has been widely demonstrated (Liu, Plowman, & Looney, 1992; Ruiz et al., 2009).

**Intellectual maturity**

For the evaluation of intellectual maturity, the Goodenough-Harris Drawing Test (GHDT), developed by Goodenough (1926) and revised by Harris (1963), was used. The GHDT test indicates the cognitive ability of the student, which in turn is represented in the intellectual maturity of the child or the metal age (MA) and a final score interpreted as intellectual quotient (IQ) (Table 1).

Table 1

*Conversion of crude score GHDT to MA*

<table>
<thead>
<tr>
<th>Months</th>
<th>0</th>
<th>3</th>
<th>6</th>
<th>9</th>
<th>3</th>
<th>6</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ages</td>
<td>0</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
<td>24</td>
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<td></td>
<td>1</td>
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<td>20</td>
<td>24</td>
<td>28</td>
<td>32</td>
<td>36</td>
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<td></td>
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<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
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<tr>
<td></td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>13</td>
<td>17</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
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<td>6</td>
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<td>13</td>
<td>17</td>
<td>21</td>
<td>25</td>
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<td></td>
<td>12</td>
<td>16</td>
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<td>28</td>
<td>32</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>19</td>
<td>23</td>
<td>27</td>
<td>31</td>
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<tr>
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<td>18</td>
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<td></td>
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<td>31</td>
<td>35</td>
<td>39</td>
<td>43</td>
<td>47</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note: Source: Harris (1963)*

The present study used the most recent edition in which the child is asked to make two drawings, one of a man and one of a woman of a whole body (Soto, Mendoza, & Ramírez, 2009). The evaluation focuses on the details and the proportion of the general body of the figure drawn from a man (73 details) and a woman (71 details). We used the average crude score of the two drawings which was the total details performed. The GHDT test was designed to evaluate both children and adolescents up to 15 years of age.

The GHDT test has several editions, all validated. The GHDT showed good reliability and validity compared to other tests of intelligence in children aged 3 to 15 (Abell, Horkheimer, & Nguyen, 1998; Plbrukarn & Theeramanoparp, 2003). The GHDT had not yet been examined from a modern test theory perspective in full. However, Campbell & Bond (2017) revealed that the GHDT and mainly the children’s human figure drawings are proper according to Rasch analysis and deem to be generally psychometrically sound.

In addition, a Cohen's Kappa coefficient was calculated to determine the effect of chance. According to Sim & Wright (2005) the concordance between the measurements of two researchers in the GHDT is proper given that the Kappa value is 0.621 (Table 2) being between 0.6 and 0.8 (good concordance).
Table 2
Cohen’s Kappa coefficient

<table>
<thead>
<tr>
<th>Measure of Agreement</th>
<th>Kappa</th>
<th>Asymp. Std. Error</th>
<th>Approx. T</th>
<th>Approx. Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.621</td>
<td>.063</td>
<td>27.049</td>
<td>.000</td>
</tr>
</tbody>
</table>

Academic performance

The school grades were required of the teachers to measure the academic performance of the students. The required school grades were: Spanish Language, Maths, Natural Sciences, Social Sciences, Physical Education, Arts, Music and English Language. The school grades were presented in a range of 0-10. Finally, the average was calculated that was the score used for the statistical calculations. School grades as a reliable measure to determine academic performance, have been supported by authors such as Lambating & Allen (2002) and Allen (2005) who determine that school grades justify the student's learning objectives.

Procedure

Once the appropriate permits were obtained from the schools and the informed consent from the parents, the different tests were administered. Two separate sessions were conducted by a trained researcher. The GHDT was evaluated during the first test session, in the school classroom and in the presence of the teacher. The examiner gave the children two sheets, one to draw the man and another to draw the woman. The students were previously instructed to draw with as much detail as possible but through free draw. In the second session, the anthropometric measures (weight and height) were carried out followed by the Leger test. Before the execution of this test, a demonstration of how they should execute it was made. The children performed a typical warm-up consisting of 5 minutes of smooth running and 5 minutes of general exercises (i.e., jumping, raising the legs, side and front races, arm rotations, etc.). Each child was evaluated individually. Both physical and cognitive tests were evaluated by a previously trained researcher. Children were encouraged to achieve the highest possible performance by motivating them with a small reward such as extra credit for those classes if they participated in the study. Finally, school grades were required of the teachers to measure the academic performance.

Statistical Analysis

Data were analysed using the program SPSS (version 21, SPSS Inc., Chicago, Ill.) for Windows. The significance level was set at p<0.05 and p<0.01. The data are shown as descriptive statistics including mean, standard deviation (SD) and percentages. Tests for normal distribution and homogeneity (Kolmogorov-Smirnov & Levene’s, respectively) were...
conducted on all data before analysis. Analysis of variance (ANOVA) was conducted for the genders comparison. Additionally, effect sizes for group differences were expressed as Cohen’s d (Cohen, 1988); effect sizes of less than 0.4 represented a small difference, whereas effect sizes of 0.41–0.7 and greater than 0.7 represented moderate and large differences, respectively (Thomas, Silverman, & Nelson, 2015). Pearson correlation was carried out among intellectual maturity, BMI, academic performance and cardiorespiratory resistance. In addition, a scatter plot was developed between cardiorespiratory endurance and intellectual maturity with genders adjust. In the end, regression analyses were developed between intellectual maturity and academic performance.

**Results**

Table 3 shows the results of age, anthropometric characteristics, cardiorespiratory endurance, intellectual maturity and academic performance with gender adjust. Boys showed greater cardiorespiratory resistance than girls, but no significant differences were found in the other variables.

<table>
<thead>
<tr>
<th></th>
<th>Girls Mean (SD)</th>
<th>Boys Mean (SD)</th>
<th>F</th>
<th>p-value</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>10.72 (0.74)</td>
<td>10.67 (0.72)</td>
<td>0.232</td>
<td>0.631</td>
<td>0.0684</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>38.74 (7.33)</td>
<td>41.46 (10.96)</td>
<td>3.06</td>
<td>0.082</td>
<td>0.2917</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.45 (0.80)</td>
<td>1.46 (0.80)</td>
<td>0.364</td>
<td>0.547</td>
<td>0.0125</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>18.17 (3.06)</td>
<td>19.07 (3.83)</td>
<td>2.45</td>
<td>0.120</td>
<td>0.2596</td>
</tr>
<tr>
<td>Leger test</td>
<td>3.13 (1.44)</td>
<td>3.98 (1.65)</td>
<td>11.113</td>
<td>0.001</td>
<td>0.5902</td>
</tr>
<tr>
<td>(number of periods)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V0₂ (ml/kg/min)</td>
<td>43.89 (3.69)</td>
<td>45.95 (4.13)</td>
<td>10.11</td>
<td>0.002</td>
<td>0.5260</td>
</tr>
<tr>
<td>Average crude score GHDT (0-73)</td>
<td>35.03 (8.32)</td>
<td>32.64 (9.78)</td>
<td>2.40</td>
<td>0.123</td>
<td>0.2632</td>
</tr>
<tr>
<td>Average school grades</td>
<td>7.69 (1.76)</td>
<td>7.45 (1.85)</td>
<td>1.195</td>
<td>0.432</td>
<td>0.1349</td>
</tr>
</tbody>
</table>

*Note: SD (Standard deviation); BMI (Body mass index); V0₂ Oxygen consumption); GDHT (Goodenough-Harris Drawing Test)*

In Table 4, the intellectual maturity of the students is positively associated with cardiorespiratory resistance, specifically with VO₂max (r = 0.415, p < 0.01). In addition, BMI...
and intellectual maturity show a negative association \((r = -0.313, p < 0.01)\). Regarding academic performance, it is also positively associated with the Leger test \((r = 0.268, p < 0.01)\) and intellectual maturity \((r = 0.799, p < 0.01)\).

Table 4

*Pearson correlation between intellectual maturity, BMI, the Léger test, \(VO_2\)max and academic performance*

<table>
<thead>
<tr>
<th></th>
<th>Intellectual maturity</th>
<th>BMI</th>
<th>Léger test</th>
<th>(VO_2)max</th>
<th>Academic performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intellectual maturity</td>
<td>1.000</td>
<td>-0.313**</td>
<td>0.410**</td>
<td>0.415**</td>
<td>0.799**</td>
</tr>
<tr>
<td>BMI</td>
<td>1.000</td>
<td>-0.436**</td>
<td>-0.422**</td>
<td>-0.120</td>
<td></td>
</tr>
<tr>
<td>Léger test</td>
<td>1.000</td>
<td>0.983**</td>
<td>0.268**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(VO_2)max</td>
<td></td>
<td></td>
<td>1.000</td>
<td>0.067</td>
<td></td>
</tr>
<tr>
<td>Academic performance</td>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
<td></td>
</tr>
</tbody>
</table>

*Note: BMI (Body Mass Index); \(VO_2\)max (maximum oxygen consumption); GDHT (Goodenough-Harris Drawing Test). ** p < 0.05*

Figure 1 shows the scatter plot between intellectual maturity and \(VO_2\)max according to gender. As the cardiorespiratory endurance of the students increases, their intellectual maturity increases.

![Figure 1. Dispersion figure between intellectual maturity and \(VO_2\)max adjusted by gender](image)
The intellectual maturity is a good indicator of academic performance in children of school age. For this, the linear regression model (Table 5) shows that intellectual maturity is positive predictor of academic performance ($R^2=0.638$, $p<0.05$).

Table 5

**Multiple linear regressions between intellectual maturity and academic performance**

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>T</th>
<th>p-value</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Higher limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower limit</td>
</tr>
<tr>
<td>Academic performance</td>
<td>2.861</td>
<td>16.139</td>
<td>0.000</td>
<td>0.125</td>
</tr>
<tr>
<td>Intellectual maturity</td>
<td>0.142</td>
<td>9.301</td>
<td>0.000</td>
<td>2.253</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.142</td>
<td>9.301</td>
<td>0.000</td>
<td>0.638</td>
</tr>
</tbody>
</table>

Figure 2 shows the drawings of a woman and a man made by an 11-year old girl in 6th grade of primary education with high scores on the GHDT and high average school grades. Those scores agree with an appropriate VO2max according to the references of Hamlin et al. (2014). On the other hand, the drawing of another girl from the same school year with low GHDT score and low average school grades is also associated with an inappropriate VO2max.

*Figure 2. Drawings of girls in 6th grade of Primary Education*

*Note: Chronological age (CA); Mental age (MA); maximum oxygen consumption (VO2max)*
Discussion

The purpose of this study was to analyse the relationship between intellectual maturity and cardiorespiratory resistance in children 10-12 years old. The main finding shows that children’s intellectual maturity is associated with cardiorespiratory resistance. In addition, intellectual maturity is a predictor of academic performance.

In a similar study, Latorre et al. (2016) found significant associations between GHDT and physical fitness in preschool children; thus, from an early age, physical-motor performance and intellectual maturity are linked, being the physical fitness a good tool to determine it.

In turn, several authors have found an association between cognitive and motor development in children aged 5 to 12 years (Chaddock, Pontifex, Hillman & Kramer, 2011; Niederer et al., 2011). However, this relationship may be direct or may be affected by other factors, such as the influence of parents. Wassenberg et al. (2005) showed the parallel development of cognitive and motor-specific performance in children during normal or late development; some specific brain structures, such as the basal ganglia or frontal cortex and the transmission of dopamine, develop in parallel with some cognitive aspects. Niederer et al. (2011) found that increased cardiorespiratory fitness, motor skills and dynamic balance correspond with a better memory of spatial work and attention in school-age children. Additionally, Krombholz (2006, 2013) found positive correlations between the measures of physical growth and physical performance and between motor performance and cognitive performance, physical fitness, body coordination and manual dexterity in children, which improved with age.

On the other hand, BMI was negatively correlated with the GHDT and the cardiorespiratory fitness test. According to a study about nutritional status and intelligence quotient (IQ), a better nutritional status was associated with a higher IQ (Suvarna & Itagi, 2009). Likewise, Li et al. (2008) found that an increase in body weight is related to a reduction in the general mental ability in children. Gunstad et al. (2008) noted that high BMI is not associated with cognitive function in healthy children and adolescents. Likewise, Latorre et al. (2016) did not find a relationship between BMI and GHDT in preschool children. Therefore, the results are controversial and require more research to clarify the association between weight status and cognition in children.

According to Janssen et al. (2010), there are a myriad of not only physical but also cognitive benefits when children perform physical activity; therefore, policies that facilitate the realisation of physical activity for this population are needed. Chaddock et al. (2011) carried out a systematic review in which the importance of physical activity and cardiorespiratory capacity to maximise brain health and cognitive function during development was shown.

The pre-pubertal period offers many opportunities to stimulate cognitive function. However, the relationship between participation in PA and cognitive performance has been a subject of discussion between advocates and sceptics of physical activity, as well as parents concerned about decreases in study and homework time. Additionally, opportunities to be physically active at school are limited because of pressure to perform well academically (Mahar et al., 2006; O’Dwyer et al. 2013). However, participation in physical activity is not associated with less time dedicated to study (Jonatan R Ruiz et al., 2010). An additional curricular
emphasis on PE may result in significant gains in cognitive performance. In this regard, the literature suggests that academic achievement, physical fitness and health of children will not be improved by limiting the time allocated to PE and physical activity (Trudeau & Shephard, 2008).

Academic performance and intellectual maturity have been linked according few research (Pérez, 1996; Berrios Aguayo, Latorre Román, & Pantoja Vallejo, 2017). Therefore, this is strength of our research as it demonstrates a little but relevant academic studied issue. If from an improvement of the cardiorespiratory resistance of the students their mental age is increased, this in turn would be making benefits in terms of academic performance.

A limitation of this study is its cross-sectional design, so caution should be exercised in interpreting the associations observed. More studies are needed to provide adequate evidence of causality through longitudinal records. Regarding the development of health in school, it is necessary to emphasise that there is a large connection between body growth, physical fitness and cognition. Therefore, increasing the amount of time spent in physical education can promote cognitive benefits and improve the health of school-age children.

In conclusion, from an early age cardiorespiratory endurance and mental age seem to be related. This link is a good training tool for cognitive development in children 10-12 years old.

Reference


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