Alexandria Journal of Medicine xxx (2017) xxx–xxx

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Contents lists available at ScienceDirect

Alexandria Journal of Medicine

journal homepage: http://www.elsevier.com/locate/ajme

Original Article

Relationship between motor and cognitive learning abilities among primary school-aged children

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ARTICLE INFO

Article history:
Received 15 November 2016
Revised 22 December 2016
Accepted 22 December 2016
Available online xxxx

Keywords:
Physical fitness
Intellectual performance
Child development

ABSTRACT

Background: The relationship between motor and cognitive development has already been proven in young children. However, in relation to the academic achievement the association between motor and cognitive performance still not well established. Therefore, the aim of this study was to examine the levels of motor and cognitive learning abilities and their independent and combined associations among German primary school-children.

Methods: Participants were (n = 197) between the ages of six to eight. The German motor test (DMT), the cognitive abilities test (KFT), height, weight, and body mass index (BMI) were measured.

Results: ANOVA testing found that boys perform better in long jumping and in the six minutes running test while girls perform better in balancing backwards and in deductive thinking test ($p < 0.05$). With maturation from ages six to eight the achievement level of both populations showed a higher performance in motor and cognitive learning abilities ($p < 0.001$). Concerning the combined and independent associations between the tested abilities, a significant correlation was shown between total motor and total cognitive learning abilities ($p < 0.001$, $r = 0.60$) with higher contribution of balancing backwards, six minutes running and push-up levels ($r = 0.63$, $r = 0.62$, $r = 0.60$, respectively) in the performance of the cognitive learning abilities (i.e. mathematical thinking, $r = 0.62$ and language understanding, $r = 0.59$).

Conclusions: In conclusion, fostering the childrens' physical fitness during the primary school age could enhance both motor and cognitive learning abilities related to the academic achievement.

1. Introduction

Currently, it is well established that both cognitive and motor abilities followed similar developmental time tables with an accelerated progression in the kindergarten and elementary school years.[1,2] Indeed, Bushnell and Boudreau[3] suggest that motor development may play a central role for further parameter development (i.e., prerequisite for cognitive development and academic learning). This suggestion has been supported by recent results which show a positive relationship between (i) intelligence quotient (IQ) and the movement speed during a sequencing task,[4] (ii) motor proficiency and fluid crystallized intelligence[5] and (iii) motor performance and working memory.[6] In the same context, Thelen[7] and Wrobel[8] supported the role of improving motor abilities in the development of cognitive functions.

With regard to the specificity of academic achievement, previous studies have examined the association of physical fitness with cognitive development and found a positive association between children's academic achievement and their physical fitness.[9–13] In this context, Dwyer et al.[14] found that physically active students were more likely to be academically motivated, alert, and successful. Iverson[15] and Preston et al.[16] show an association between infant motor development and language development which predicts school-age reading skills. Furthermore, among children a significant association was found between (i) poor

Peer review under responsibility of Alexandria University Faculty of Medicine.
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http://dx.doi.org/10.1016/j.ajme.2016.12.004
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motor performance and poor academic achievement.[17] (ii) poor gross motor performance and larger learning deficits.[18] However, few studies found no relation between physical activity and academic performance.[19,20]

In addition, based on previous result of Adkins et al.[21], who showed that the cardiorespiratory capacity (1st component of physical fitness) was related to angiogenesis (i.e., development of blood vessels), whereas muscular strength and motor ability (2nd and 3rd component of physical fitness) were associated with synaptogenesis (i.e., formation of neuronal synapses), it was suggested that physical fitness improves inhibition, working memory, and cognitive flexibility[22–24] (i.e., the three aspects involved in the cognitive control and provided the foundation for academic ability.[23,25] These findings support the results of Etnier et al.[26] and Pontifex et al.[22] which also suggest that physical fitness may play a key role in brain health and academic performance in youths.

Therefore, it is reasonable to assert, from the preponderance of available research, that there is a line of evidence supporting the theoretical assumption of a relationship existing between motor and cognitive development in young children. However, it should be noted that, neither approach has examined the association between motor and cognitive performance related to the academic achievement. Thus, the present study investigated, (i) the levels of motor and cognitive learning abilities in German children ages sex to eight (i.e. assessing differences by gender and age) and (ii) the combined and independent contribution of each motor ability component in the performance of the cognitive learning abilities (i.e., related to the academic achievement).

Differentiate which motor components are more related to the cognitive learning performance could ultimately aid in the development of targeted interventions to enhance this performance.

2. Methods

2.1. Participants and setting

Participants were primary school aged-children ($n = 197$; 101 boys and 96 girls ranging in age from six to eight (age = 7.01 ± 0.76 years old; grades 1–3). The data were collected between 2012 and 2013 in five public primary schools in the city of Magdeburg in Germany. The selection of schools was based on age, socioeconomic status, demographic characteristics and the number of students in each school. Participation was voluntary and informed written consent was obtained from the school directors, participants, and their parents or guardians before the children entered into the study. The study was conducted according to the Declaration of Helsinki. The protocol and the consent form were fully approved by the institutional ethics committee before the commencement of the assessments.

The measurement of motor abilities was carefully supervised inside the school gym by observers trained in anthropometric and motor techniques with respect to the World Health Organization (WHO) recommendations for the anthropometric tests and to the German Health Interview and Examination Survey (KiGGS) for the motor tests. A well-tested design and frequently calibrated equipment was used.

Height, weight, and Body Mass Index (BMI) were assessed for all participants. Height was measured in a standing position, without shoes, to the nearest 0.1 cm using portable gauges (Seca, Germany). The weight was performed with minimal clothing and recorded to the nearest 0.1 kg using electronic scales (Teraillon, France). BMI was defined as the ratio of body weight to body height squared, expressed in kg/m^2:weight (kg)/height^2 (m^2). The DMT was administered in a group setting during regular classes. The measurements were conducted in sessions lasting about 90 min. Five assistants helped the researchers during the realization of the test.

The cognitive learning ability test (KFT) used in the study is designed for use with children during their first three years in primary schools (i.e., six to eight years old). The test is based on guidance from the teachers and test instructors. The measurement of cognitive learning abilities was executed in a group setting, and carefully supervised in the classroom. Participating children were tested over a 60 min time interval KFT 1–3.[27]

2.2. Test description

The German motor test DMT[28] is targeted for the children ages of 6–18. This test is used to assess motor abilities, including endurance, strength, speed, coordination, flexibility and indicate general motor performance ability (MPA).[29] Assessing the motor abilities is achieved through structured motor skills like running, jumping, and balancing. Sport-specific skills are excluded in this testing. In the current study the test items measuring the sprint (i.e., 20 m sprint), coordination (i.e., balancing backwards (BB), jumping sideways (JS)), strength (i.e., push-ups (PU), sit-ups (SU), standing long jump (SLJ)), endurance (i.e., 6 min running) were used.[28]

The KFT test for cognitive learning ability is based on similarly conceptualized intelligence tests such as intelligence IQ tests. It is composed of four tests measuring cognitive learning abilities of the primary school children; grades 1–3 (KFT 1–3).[27] This test battery was developed to assess abstract intelligence and is used primarily for research in context with educational counseling, teaching differentiation and educational research. The KFT test includes items for measuring language understanding, relationship recognition, deductive and mathematical thinking. Together, these cognitive assessments indicate potential cognitive and intellectual learning of children during their first three years at school.

2.3. Validity and reliability

The validation of the motor test was based on an international expert questionnaire involving 40 selected fitness experts in 25 European countries. These experts were asked about the relevance of the test contents and the requirements in the motor performance tests with regard to the documentation of MPA.[30] All tests were checked for validity and reliability by experts in the field. The content-related validity of all tests were evaluated to be reliable. The cognitive test was validated by Heller and Geisler.[27] The authors found a good test-retest reliability coefficients for the motor and cognitive tests ($r_{min} = 0.68$ to $r_{max} = 0.94$ and $r_{min} = 0.76$ to $r_{max} = 0.84$, respectively).

2.4. Statistical analyses

All statistical tests were processed using STATISTICA Software (StatSoft, France). Values were expressed as mean ± SD. Normality was confirmed using the Shapiro-Wilks W-test. The effect of gender was analyzed using an independent *t*-test and the effect of age was analyzed using a 1-way ANOVA (3 levels [6, 7, 8 years old]) with repeated measures. Significant differences between means were assessed using Fisher's post-hoc tests. Effect sizes were calculated as partial eta-squared (η_p^2) for the ANOVA analysis and as Cohen's d for the paired sample *t*-test to assess the practical significance of our findings. The correlations between anthropometric, motor, and cognitive data were assessed by Pearson product-moment correlation. Significance was set as $p < 0.05$.