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The relationship between motor proficiency and academic performance of adolescent learners in Potchefstroom, South Africa: The PAHL Study

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Abstract

The effect of movement on academic performance has lately become a topic of interest in literature, as it is widely accepted that there is a strong relationship between motor and cognitive development. The purpose of this study was to determine the relationship between motor proficiency and academic performance of Senior Phase learners in Potchefstroom, an urban region in South Africa. A total of 236 children between the ages of 13 and 14 years were randomly selected out of eight schools. The Bruininks-Oseretsky Test of Motor Proficiency 2 was used to assess motor competency. The learners' academic performance was measured by making use of their average end-of–year academic marks and the marks of English and Mathematics. Significant correlations were found between fine motor control and the end-of-year average marks and English and Mathematics marks in some of the groups. Similarly, correlations were found between the scores of the manipulation coordination items and the English marks of most of the groups, while the end-of-year marks, English and Mathematics marks correlated with body coordination scores in most of the groups. The strength and agility items showed the strongest correlations with the end-of-year marks in all the groups, and the total motor proficiency score showed significant correlations with the end-of-year marks in all the groups. The results of this study imply that motor skill development and maintenance should be incorporated in the Physical Education curriculum for learners of this age group.

Keywords: Motor proficiency, academic performance, adolescent, learners.

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Introduction

In light of a worldwide decline in physical activity levels of children, the effect of movement on academic performance and cognitive development is enjoying increased attention in modern literature. It is well documented in literature that there is a strong relationship between motor and cognitive development (Piek, Dawson, Smith & Gasson, 2008; Loras, Stensdotter, Őhberg, & Sigmundsson, 2013; Rigoli, Piek, Kane, Whillier, Baxter & Wilson, 2013). This relationship is partly ascribed to the changes in brain function and structure that take place due to physical and motor training (Kleim, 2011).

In this regard, Kleim (2011) and Ridler et al. (2006) hold that motor training leads to an increase in the grey matter of the brain, neurons and supporting cells, and white cell matter, which includes the axons of these neurons. Another study conducted by Haapala (2013) indicates that physical activity which includes motor training, promotes cognitive functioning by means of the increased synaptic plasticity and improved neuro-electric functioning in the brain. Fredericks, Kokot and Krog (2006) subscribe to these changes by describing the body as a sensory motor response system which is responsible for the brain adapting to stimuli from the environment and organising itself accordingly.

This adaptation is the foundation for perceptual motor development (Fredericks et al., 2006), including abilities such as hand-eye coordination and body awareness which are needed to write, and spatial awareness which is essential for reading and mathematics (Fredericks et al., 2006; Carlson, Rowe & Curby, 2013). In this context, various studies have found that manual dexterity and hand-eye coordination are significant role players in academic performance (Romano, Babchishin, Pegani & Kohen, 2010; Roebers, Röthlisberger, Neuenschwander, Cimeli, Michel & Jäger, 2014).

However, some literature shows contrasting findings regarding the relationship between motor proficiency and academic performance. For instance, Nourbakshs (2006) found a significantly positive correlation between perceptual motor abilities and academic performance in 11-year-old children in Iran, while Carter (2009) discovered a relationship between the improvement of gross motor skills and mathematics performance in 9-year-old children in Texas.

Although Stephenson (2009) and Hyatt (2009) revealed evidence that perceptual motor development programmes do not influence academic learning, Fredericks et al. (2006) found correlations in the reading and mathematical skills of Grade 1-learners and their perceptual motor skills on completion of a perceptual motor intervention programme that focused on the improvement of fundamental movement skills.

Other studies show relationships between academic achievement and gross and fine motor skills in younger as well as older learners. In a study by Piek et al. (2008) on the effect of the fine and gross motor development of four-year-old children on later cognitive abilities, a significant correlation was found between the gross motor skills of four-year-olds and their cognitive abilities at school-going age. In support of these results, Rigoli et al. (2013) found that 11-year old children with better fine motor skills obtained higher scores in visual memory tests, in a study among 195 Australian children. Nourbakhsh (2006), in his study on 400 Irish children of the same age, found a correlation between their total perceptual motor proficiency score and academic performance, measured by their average final examination marks.

In older learners, Loras et al. (2013) found a correlation between motor timing and cognitive and fine motor skills in young adults in Norway, and the results of Morales, González, Guerra, Virgili and Unnithan (2011) involving 487 nine- to 16-year-old school children in Spain showed that fine motor skills and gross motor skills were significant predictors of language and mathematical skills. Rigoli et al. (2012) found a significant correlation between motor coordination and cognitive executive function among 12- to 16-year-old Australian adolescents. A study by Carlson et al. (2013), on five- to 18-year-old children in the USA, showed that the correlation between academic performance and fine motor skills can be ascribed to their levels of visual-spatial integration, especially with respect to mathematics and written expression.

A few studies on South African children show relationships between motor skills and academic aspects. For example, Pienaar et al. (2014) found a strong correlation between academic performance and visual motor integration, visual perception, hand control and motor proficiency in 812 six- and seven-year-old learners in the North-West Province.

In a study by Wessels, Pienaar and Peens (2009) on 99 six- to seven-year-old children with coordination problems in Potchefstroom, it was discovered that the skills associated with learning were significantly weaker than those of children without coordination problems. Furthermore, in the study of Van Niekerk, Pienaar, and Coetzee (2014) on the neuro-motor problems of children with learning disabilities, it was found that these children exhibited more problems related to fine motor skills, visual tracking, gross motor skills, left-right discrimination and equilibrium reactions correlating with writing, reading and mathematics, than their peers with no learning disabilities.

It is clear from the above literature that motor and cognitive skills are related and it appears that fine-, perceptual- and gross motor skills have an effect on various aspects of cognitive functioning, which can influence academic performance. Although some studies of this nature have been performed on younger South African learners (Pienaar et al., 2014; Van Niekerk et al., 2014; Wessels et al., 2009), few studies have been conducted on adolescents.

It would therefore appear that there is a gap in literature on the relationship between motor proficiency and academic performance in South African adolescents. Therefore, the aim of this study is to investigate the relationship between motor proficiency and academic performance in a group of adolescent learners in Potchefstroom.

Methodology

Research design

This study is part of larger study, namely the PAHL (Physical Activity and Health Longitudinal)-study, a multi-disciplinary longitudinal project which researched various health aspects of 13- to 18-year-old leaners over a period of five years. The current study adopted a cross-sectional design, as it is based on data collected during the first phase of the PAHL-study, thus the baseline testing of the study population.

Participants

A total of 236 learners (99 boys and 137 girls) aged between 13 and 14 years, were purposefully selected to participate in this study. The sample proportionally represented the various population groups of the Potchefstroom area.

Measuring instruments

Motor proficiency

Bruininks-Oseretsky Test of Motor Proficiency 2 (BOT-2)

The Bruininks-Oseretsky Test of Motor Proficiency 2 (BOT-2) (Bruininks and Bruininks, 2005) was used to evaluate the motor proficiency of the subjects.The BOT-2 is aimed at people between four and 21 years and consists of four components, namely fine motor control (fine motor precision and fine motor integration, which includes drawing a line between two lines, folding paper on lines, and copying a square and star), manipulation coordination (manual dexterity and upper limb coordination, including the tests of transferring coins, bouncing and catching a ball and dribbling of a ball) body coordination (balance and bilateral coordination, which includes tapping of feet and fingers, jumping in place with same sides synchronised, walking on a line, and standing on one leg) and strength and agility (running speed and agility, which includes hopping on one leg against time, push-ups and sit-ups).

For the purposes of this study, the short form was used as prescribed by the authors of the measuring instrument. The measuring instrument is gender and age specific and has been used successfully in various studies to determine motor proficiency in children (Duger, Bumin, Uyanik, Esra & Kayihan, 1999; Gallahue & Cleland Donnellly, 2003; Wrotniak, Epstein, Dorn, Katherine, Valerie & Kondilis, 2006). The total scores of the various sub-items were calculated and then converted into standard scores and percentiles.

According to the norm scale of the BOT-2, a total motor proficiency score of 67 to 69 falls on the 14^{th} to 16^{th} percentile, a score between the 3^{rd} and 17^{th} percentile is considered below average while scores between the 18^{th} and 83^{rd} percentile are considered average in the 13- to 14-year-olds category (Bruininks & Bruininks, 2005). The BOT-2 exhibits a validity of r = 0.80 (Bruininks and Bruininks, 2005), and is considered to be a valid test for motor proficiency in normal children (Kambas & Aggeloussis, 2006).

Academic performance

The learners' academic performance was measured using the average academic mark, (average of all subjects) they attained at the end of the year, as well as the average of English and Mathematics marks respectively, as indicated on the learners' end-of-year report card.

The marks for these two subjects were used because they are prevalent in research on academic performance (Korhonen & Linnanmäki, 2012; Chen & Housner, 2013; Solano-Flores Barnett-Clarke & Kachchaf, 2013). The reason for this is that certain aspects of cognitive functioning often correlate with specific perceptual motor skills (Fredericks et al., 2006; Audiffren Tomporowski & Zagrodnik, 2008).

Procedure

Permission was obtained from the district head of the Provincial Department of Education. The study was also approved by the ethics committee of the Potchefstroom campus of the North-West University (NWU-0058-01-A1).

The principals of various schools were approached to obtain permission to conduct the research, after which ethical indemnity was obtained for the study.Informed consent forms were given to the Grade 8-learners and their parents at the beginning of the study.

The BOT-2 tests, as described above, were performed at the schools by the researchers and Honours students who were specifically trained to conduct the BOT-2.

Data analysis

Descriptive statistics (means, standard deviations, and minimum and maximum values) were used to analyse data. Correlations between the results of the motor proficiency tests and the academic marks were further analysed using Spearman correlation coefficients.

Results were considered statistically significant where $p \leq 0.05$. To determine the practical significance of the correlations, the correlation coefficients were used as effect sizes (ES) according to the guidelines of Cohen (1988) and Steyn (2006) for practical significance in correlation research. These researchers recommend that a correlation coefficient of 0.1 represents a small effect, 0.3 a medium effect and 0.5 a large effect (Cohen, 1988; Steyn, 2006). All statistical analysis were performed by the Statistical Services of the North-West University.

Results

The descriptive statistics on the results of the motor proficiency tests and the academic performance according to the BOT-2 and the marks on the report cards of the learners are displayed in Table 1. The mean BOT-2 total of the 13- to 14-year-old boys and girls (67.5) lies between 67 and 69, which, on to the norm scale of the BOT-2, falls on the 14^{th} to 16^{th} percentile (Bruininks & Bruininks, 2005).

The mean total BOT-2 score of the boys fell on the 16^{th} percentile, while the girls fell on the 14^{th}, respectively. Looking at the categories of the BOT-2, the motor proficiency of the total group of learners, as well as the boys and the girls, were below average for their age.

If the scores obtained for each of the test items are compared with the possible maximum score, it would appear that the fine motor control component (especially where subjects were required to copy a star), body coordination (especially jumping in place) and strength and agility (hopping on one leg, sit-ups and push-ups) all contributed to the below average total scores.

With reference to the academic marks of the subjects, it was found that the English marks of the total group were below average, as well as those of the boys and girls. The same tendency was found in Mathematics in girls and boys, which were below the average percentage of 43.4%. If, however, the end-of-year averages are taken into account, the groups obtained an average mark of 52.4%.

Table 2 shows the correlation coefficients between the motor proficiency and academic performance scores. It is apparent that there were positive correlations between the academic marks and all the components of the BOT-2. Statistically significant correlations ($p \leq 0.05$) were found between the drawing of a line between two lines and the paper folding tests in the fine motor control component, and the end-of-year average marks of the total group and girls' group, while there were also correlations in English (total group) and

Mathematics (total group and girls' group). All these correlations in the total group exhibit a small practical significance (between $r = 0.15$ and $r = 0.19$), while the correlations found in the girl's group, exhibited a small to a medium effect (between $r = 0.21$ and $r = 0.29$).

In the manipulation coordination components of the BOT-2, statistically significant correlations of a small effect (between $r = 0.16$ and $r = 0.23$) were found between test results for transferring coins and the English marks of all the groups.

The body coordination tests revealed statistically significant correlations in the tests for tapping fingers and feet (end-of-year mean scores of the total group and girls), as well as correlations in the tests for jumping in place (end-of-year average marks of the boys) and standing on one leg (end-of-year marks of the girls), all with practical significance of a small effect (between $r = 0.21$ and $r = 0.26$).

Table 1: Descriptive statistics for motor proficiency and physical activity in 13- to 14-year-old learners

Sub-item and maximum score	Total group (n=239)				Boys (n=98)				Grils (n=141)			
	M	*SD*	Min	Max	M	*SD*	Min	Max	M	*SD*	Min	Max
Fine motor control												
Draw line between 2 lines (0 mistakes)	1.36	1.75	0	9	1.23	1.31	0	7	1.45	1.67	0	9
Fold paper on lines (12 correct folds)	9.85	2.92	0	12	9.72	2.03	0	12	10	1.98	0	12
Copy a square (5 marks)	4.1	0.92	0	5	4.34	0.78	1	5	3.96	0.76	0	5
Copy a star (5 marks)	3.07	1.06	0	5	3.37	0.98	0	5	2.95	1.04	0	5
Manipulation coordination												
Transferring coins (20 coins)	17.1	2.47	8	20	17.24	2.65	9	20	17.15	2.44	8	20
Body coordination												
Tap feet and fingers (10 taps)	9.88	0.64	4	10	9.9	0.65	4	10	9.87	0.63	5	10
Jumping in place (5 jumps)	3.34	1.73	0	5	3.3	1.78	0	5	3.37	1.7	0	5
Walk a line (6 steps)	5.53	0.89	1	6	5.44	1.05	1	6	5.61	0.77	3	6
Standing on one leg (10 sec.)	9.27	1.69	2	10	9.37	1.75	2	10	9.21	1.66	3	10
Upper limb coordination												
Bounce and catch ball (5 catches)	4.97	0.21	3	5	4.99	0.1	4	5	4.96	0.26	3	5
Dribble of the ball (10 dribbles)	9.01	2.01	3	10	9.06	1.89	3	10	8.96	2.09	3	10
Strength and agility												
Hopping on one leg (≥50 hops)	41.5	10.5	12	80	42.5	11.54	12	69	40.8	9.63	16	80
Push-ups (≥36 push-ups)	13.8	5.87	0	40	16.3	6.22	2	40	12	4.93	0	30
Sit-ups (≥36 sit-ups)	11.6	5.14	0	25	13.5	4.71	2	25	10.2	5.03	0	22
Motor proficiency (BOT-2 total)	67.5	5.18	55	85	69.53	6.35	55	84	67.4	7.67	56	80
Academic performance												
Mathematics marks	43.4	15.91	3	94	42.11	17.7	14	98	44	18.2	2	85
English marks	48.8	18.04	2	98	47.93	14.31	25	87	49.67	15.8	3	94
End-of-year marks	52.4	14	4.11	85.22	51.01	12.07	23.3	83.89	53.39	15.1	4.11	85.22

Min = minimum value; Max = maximum value; M = mean value; SD = standard deviation

Table 2: Correlation coefficients (*r*) between motor proficiency and academic performance in 13- to 14-year-old learners

Variables	Total group (n = 256)			Boys (n=100)			Girls (n= 156)		
	Eng	Math	M	Eng	Math	M	Eng	Math	M
Fine motor control									
Draw line between 2 lines	0.06	0.16*	0.19*	-0.08	0.09	0.01	0.13	0.21*	0.28*
Fold paper on line	0.15*	0.13*	0.18*	0.15	0.11	-0.01	0.14	0.15	0.29*
Copy a square	0.11	0.01	0.01	0.08	-0.03	-0.03	0.14	0.03	0.04
Copy a star	0.07	0.07	0.13	0.12	0.05	0.15	0.12	0.05	0.15
Manipulation coordination									
Transfer coins	0.16*	0.06	0.05	0.23*	0.11	0.02	0.23*	0.11	0.1
Bounce and catch ball	0.01	0.05	0.07	0.02	0.02	0.07	0.02	0.02	-0.18
Dribble ball	0.02	0.03	0.01	0.05	0.02	-0.08	0.05	0.02	0.06
Body coordination									
Tap feet and fingers	0.01	0.13	0.21*	0.06	0.23*	0.1	0.06	0.23*	0.26*
Jumping in place	0.03	0.09	0.12	0.07	0.04	0.29*	0.07	0.04	0.02
Walk a line	0.06	0.06	0.01	0.03	0.08	0.07	0.03	0.08	0.07
Standing on one leg	0.02	0.06	0.09	0.16	0.15	-0.08	0.16	0.15	0.24*
Strength and agility									
Hopping on one leg	0.12	0.18*	0.27*	0.1	0.23*	0.41*	0.1	0.23*	0.19*
Push-ups	0.09	0.11	0.23*	0.24*	0.21*	0.24*	0.24*	0.21*	0.31*
Sit-ups	0.12	0.29*	0.36*	0.26*	0.39*	0.34*	0.26*	0.39*	0.42*
Motor proficiency (BOT-2 total)	0.12	0.23*	0.34*	0.21*	0.26*	0.29*	0.21*	0.26*	0.40*

Eng = English; Math = Mathematics; M = average end of-year mark; * = statistical significance where $p \leq 0.05$; Practical significance r>0.1 =small, r >0.3=medium, r >0.5=large effect

The most correlations were found in relation to the strength and agility component of the BOT-2. Statistically significant correlations were found for the hopping on one leg test (end-of-year marks of the total group, boys' groupand the girls' group, with a small to medium practical significance; r = 0.18 to r = 0.41), the push-ups (end-of-year average marks of the total group, girls' and boys' groups, as well as the Mathematics and English marks for both boys and girls), and especially in the sit-ups (all the marks of all the groups, except for the English marks of the total group correlated positively). The correlations found in the push-ups and sit-ups exhibited a practical significance of small to medium effect (between r = 0.15 and r = 0.44). Furthermore, the total motor proficiency score (total BOT-2 score) reveals statistically significant correlations of small to medium effects (r = 0.21 to r = 0.40) with the Mathematics and the end-of-year average marks of all the groups.

Discussion

The aim of the study was to investigate the relationship between motor proficiency and academic performance in Senior Phase learners. The results show significant positive correlations, although mainly of small effects, between the academic marks of the learners and all the components of the BOT-2.

The correlation between the academic marks of the learners and the fine motor control tests of drawing a line between two lines and folding a paper, supports the findings of various studies that found correlations between fine motor skills and cognitive functioning (Cameron, Brock, Murrah, Bell, Worzalla, Grissmer & Morrison, 2012; Roebers et al., 2014; Rigoli et al., 2013). Cameron et al. (2012) found significant positive correlations between fine motor skills and cognitive executive function in three- to four-year-old children, and that both of these aspects are predictors for performance in pre-school entrance tests. Roebers et al. (2014) found corresponding results on fine motor skills and cognitive executive function in five- to six-year-old children. However, these researchers stress that cognitive executive function plays a greater role in predicting academic performance than motor skills. In contrast, Carleson et al. (2013) found no relation between academic performance and visual-motor control, an aspect of fine motor control, in five- to 18-year-old children, although their results showed a correlation between academic performance and visual-spatial integration.

Manipulation coordination comprises the control and coordination of the arms and hands, specifically for the manipulation of objects (Bruininks & Bruininks, 2005). Although studies have found correlations between manipulation coordination and academic or cognitive results (Asonitou, Koutsouki, Kourtessis & Charitou, 2012; Rigoli et al., 2012; Chen & Housner, 2013), different tests were used to test aspects of manipulation, among others catching a bean bag and rolling a ball towards a target (Asonitou et al., 2012), catching of and aiming with a ball (Rigoli et al., 2012), and kicking, throwing and dribbling skills (Chen & Housner, 2013). In contrast to the positive correlations found in the research mentioned above between ball skills and academic or cognitive skills, no correlation was found in the current study between ball skills (bouncing and catching, and dribbling a ball) and academic performance, which is congruent with the results of Morales et al. (2011) among 16- to 17-year–olds. Significant positive correlations were, however, found between the English marks and results of the manipulation coordination test of transferring coins.

The test of tapping feet and fingers addresses body coordination and entails control over and coordination of the large muscle groups of the body to maintain posture and balance, as well as the coordination of the upper and lower parts of the body (Bruininks & Bruininks, 2005). The correlations between the results of this test and the academic marks of the subjects agree with the findings of Nourbakshs (2006), who found relationships between end-of-year marks and perceptual motor synchronised symmetrical and unsynchronised asymmetrical voluntary movement in 10- to 11-year-old children in Iran. This researcher also found a relationship between end-of-year marks and static balancing skills in girls, consistent with the correlation between standing on one leg and average end-of-year marks found in the group of girls in the current study. Other research found further correlations between dynamic balancing skills and Mathematics (Vuijk, Hartman, Mombang, Scherder, Visscher & Visscher, 2011), later cognitive abilities (Piek et al., 2008), cognitive processing (Asonitou et al., 2012) and spatial working memory (Niederer Kriemler, Gut, Hartmann, Schindler & Barral, 2011).

In the current study, most correlations were found between academic marks and scores in the agility and strength tests. These results are supported by the studies of Nourbakshs (2006) who found correlations between speed of movement and end-of-year marks, Katić and Bala (2012), who discovered correlations between agility and cognitive skills in ten- to 14-year old children, and Sheppard and Young (2006), who emphasize the relationship between agility and cognitive components such as visual scanning and problem solving. Furthermore, several studies undertaken to investigate the relationship between physical fitness and academic performance or cognitive functions, have found correlations with the physical fitness component of strength (Chih & Chen, 2011; Du Toit et al., 2011; Rodenroth, 2012).

The correlations with academic performance found in the various subsections of the BOT-2, are consolidated in the correlations between the total motor proficiency scores (BOT-2 totals) and the academic marks of all the groups. In support of this, Haapala (2013) found in a review study, which included correlations between motor skills and academic performance, that children with good general perceptual motor skills exhibit better average academic grades than children who possess weaker general perceptual motor abilities.

The underlying mechanisms of the correlation between motor skills and academic performance or cognitive skills are linked in literature to the areas of the brain where cognitive and motor processes take place. Researchers (Carlson et al., 2013; Rigoli et al*.*, 2013; Deng, Ding, Wu, Zhang, Li & Shen, 2014) indicate that the link between motor skills and certain cognitive processes are found in corresponding underlying processes in the cerebellum, prefrontal cortex and basal ganglia. This theory is supported by proof of the changes in brain function and structure that take place as a result of motor training (Kleim, 2011; Ridler et al., 2006). Although the link between motor skills and cognitive development is generally recognised in literature (Morales et al., 2011; Rigoli et al., 2013; Stodden & Holfelder, 2013), it is argued by researchers (Gallahue & Ozmun, 2006; Roebers et al., 2014) that there is insufficient proof in the literature to state that the improvement in motor skills will improve academic performance. However, Haapala (2013) points out that various studies link various aspects of academic performance and cognitive executive function (for example, working memory and inhibitory control) with motor skills, which is an indication of the specificity of the effect of motor development on cognitive processes. This statement concurs with the differences in correlations with English and Mathematics marks found in this study.

Conclusions

From the results of this study it is clear that various aspects of motor proficiency are linked to academic performance in this group of adolescent learners. Although a cause-and-effect relationship can't be claimed here, the results of this study do indicate that motor skills play a fundamental role in the academic performance of Senior Phase learners and therefore can have an effect on their cognitive perfomance.

In the light of this emphasis on the value of developing and improving the motor skills of adolescent learners, the recommendation is made that Senior Phase learners should take part in regular physical activity, which promotes the development and improvement of motors skills. Motor skills development should also be included in the Physical Education curriculum for the Senior Phase, to contribute to their cognitive development and academic performance.

The results of this study are subject to some limitations, namely that the group of subjects was relatively small and from one area of South Africa, which limits the generalisability of the findings. It is therefore recommended that future studies make use of a larger group of subjects from various areas in South Africa. Further research can also be conducted on the differences between genders regarding correlations between motor proficiency and academic performance in this age group, as well as differences in correlations between specific motor proficiency items and English and Mathematics marks, as it appears that the correlations differed among the various groups.

References

Asonitou, K., Koutsouki, D., Kourtessis, T. & Charitou, S. (2012). Motor and cognitive performance differences between children with and without developmental coordination disorder (DCD). *Research in Developmental Disabilities*, 33, 996–1005.

Audiffren, M, Tomporowski, P.D. & Zagrodnik, J. (2008). Acute aerobic exercise and information processing: Energizing motor processes during a choice reaction time task. *Acta Psychologica*, 129, 410–419.

Bruininks, R.H. & Bruininks, B.D. (2005). *Bruininks-Oseretsky Test of Motor Proficiency* (2nd ed.). Circle Pines, MN: American Guidance Service.

Cameron, C.E., Brock, L.L., Murrah, W.M., Bell, L.H., Worzalla, S.L., Grissmer, D. & Morrison, F.J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development*, 83(4), 1229–1244.

Carlson, A.G., Rowe, E. & Curby, T.W. (2013). Distengling fine motor skills' relations to academic achievement: The relative contributions of visual-spatial integration and visual-motor coordination. *Journal of Genetic Psychology*, 174(5), 514-533.

Carter, R.D. (2009). The effectiveness of a sensory motor lab in improving fine and gross motor skills and academic achievement in third-grade students in a rural central Texas elementary school. *Humanities & Social Sciences*, 69(12), 4635.

Chen, H. & Housner, L. (2013).The relationship among health-related fitness, motor skills performance, and physical activity in middle school students. *Asian Journal of Exercise & Sports Science,* 10(2), 11-23.

Chih, C.H. & Chen, J. (2011). The relationship between physical education performance, fitness tests and academic achievement in elementary school. *International Journal of Sport and Society*, 2(1), 66-73.

Cohen, J. (1988). *Statistical Power Analysis* (2nd ed.) (pp. 205). New York: Academic Press.

Deng, S., Li, W.G., Ding, J., Wu, J., Zhang, Y., Li, F. & Shen, X. (2014). Understanding the mechanisms of cognitive impairments in developmental coordination disorder. *Pediatric Research*, 75(1-2), 210-216.

Du Toit, D., Pienaar, A.E. & Truter, L. (2011). Relationship between physical fitness and academic performance in South African children. *South African Journal for Research in Sport, Physical Education and Recreation*, 33(3), 23-35.

Duger, T., Bumin, G., Uyanik, M., Esra, A. & Kayihan, H. (1999). The assessment of Bruininks-Oseretsky test of motor proficiency in children. *Developmental Neurorehabilitation*, 3(3), 125-131.

Fredericks, C.R., Kokot, S.J. & Krog, S. (2006). Using a developmental movement programme to enhance academic skills in grade 1 learners. *South African Journal for Research in Sport, Physical Education and Recreation*, 28(1), 29-42.

Gallahue, D.L. & Cleland Donnellly, F.C. (2003). *Developmental Physical Education for all children*. Champaign, IL: Human Kinetics.

Gallahue, D.L. & Ozmun, J.C. (2006). *Understanding Motor Development: Infants, Children, Adolescents, Adults* (3rd ed.). Madison, Wis.: Brown & Benchmark.

Haapala, A.E. (2013). Cardiorespiratory fitness and motor skills in relation to cognition and academic performance in children – A Review. *Journal of Human Kinetics*, 36, 55-68.

Hyatt, K.J. (2009). A review of three controversial educational practices: perceptual motor programs, sensory integration, and tinted lenses. *Education and Treatment of Children*, 32(2), 313-342

Kambas, C.A. & Aggeloussis, N. (2006). Construct validity of the Bruininks-Oseretsky test of motor proficiency-short form for a sample of Greek preschool and primary school children. *Perceptual and Motor Skills*, 102, 65-75.

Katiċ, B. & Bala, G. (2012). Relationships between cognitive and motor abilities in female children aged 10–14 years. *Collegium Antropologicum,* 36 (1), 69–77.

Kleim, J. (2011). Exercise and the brain: Exciting discoveries underscore how exercise benefits brain health and boosts lifelong learning. *Fitness Journal*, 1, 74-76.

Korhonen, J. & Linnanmäki, K. (2012). Language and mathematical performance: A comparison of lower secondary school students with different level of mathematical skills. *Scandinavian Journal of Educational Research*, 56(3), 333–344.

Loras, H., Stensdotter, A., Őhberg, F. & Sigmundsson, H. (2013). Individual differences in motor timing and its relation to cognitive and fine motor skills. *Plos One*, 8(7), e69353.

Morales, J., González, L., Guerra, M., Virgili, C., Unnithan, V. (2011). Physical activity, perceptual-motor performance, and academic learning in 9-to-16-year-old school children. *International Journal of Sport Psychology*, 42(4), 401-415.

Niederer, I., Kriemler, S., Gut, J., Hartmann, T., Schindler, C., Barral, J. (2011). Relationship of aerobic fitness and motor skills with memory and attention in pre-schoolers (Ballabeina): A cross-sectional and longitudinal study. *BMC Pediatrics*, 11, 34.

Nourbakhsh, P. (2006). Perceptual-motor abilities and their relationship with academic performance of fifth grade pupils in comparison with Oseretsky scale. *Kinesiology*, 38(1), 40-48.

Piek, J.P., Dawson, L., Smith, L.M. & Gasson, N. (2008). The role of early fine and gross motor development on later motor and cognitive ability. *Human Movement Science*, 27, 668–681.

Piek, J.P., Dworcam, M., Barrett, N.C. & Coleman, R. (2000). Determinants of self-worth in children with and without developmental coordination disorder. *International Journal of Disability, Development and Education*, 47, 259-272.

Pienaar, A.E., Barhorst, R. & Twisk, J. (2014). Relationships between academic performance, SES school type and perceptual-motor skills in first grade South African learners: NW-CHILD study. *Child: Care, Health & Development*, 40(3), 370-378.

Ridler, K., Veijola, J.M., Tanskanen, P., Miettunen, J., Chitnis, X., Suckling, J., Murray, G.K., Haapea, M., Jones, P.B., Isohanni, M.K. & Bullmore, E.T. (2006). Fronto-cerebellar systems are associated with infant motor and adult executive functions in healthy adults but not in schizophrenia. *National Academy of Sciences*, 103(42), 15651–15656.

Rigoli, D., Piek, J.P., Kane, R., Whillier, A., Baxter, C. & Wilson, P. (2013). An 18-month follow-up investigation of motor coordination and working memory in primary school children. *Human Movement Science*, 32, 1116–1126.

Rodenroth, K.A. (2012). Study of the relationship between physical fitness and academic performance: Dissertation Abstracts International Section A. *Humanities and Social Sciences*, 71(11-A), 3891.

Roebers, C.M., Röthlisberger, M., Neuenschwander, R., Cimeli, P., Michel, E. & Jäger, K. (2014). The relation between cognitive and motor performance and their relevance for children’s transition to school: A latent variable approach. *Human Movement Science*, 33, 284–297.

Romano, E., Babchishin, L., Pegani, L.S. & Kohen, D. (2010). School readiness and later achievement: Replication and extension using a nationwide Canadian survey. *Developmental Psychology*, 46(5), 995–1007.

Sheppard, J.M. & Young, W.B. (2006). Agility literature review: Classifications, training and testing. *Journal of Sports Sciences*, 24(9), 919 – 932.

Solano-Flores, G., Barnett-Clarke, B. & Kachchaf, R.R. (2013). Semiotic structure and meaning making: the performance of English language learners on mathematics tests. *Educational Assessment*, 18,147–161.

Statsoft. (2012). *Statistica for Windows. Release 5.5: General Conversations and Statistics*. Tulsa, OK: Statsoft.

Stephenson, J. (2009). Best practice? Advice provided to teachers about the use of Brain Gym® in Australian schools. *Australian Journal of Education,* 53(2), 109-124.

Steyn, H.S. (2006). Handleiding vir bepaling van effekgrootte-indekse en praktiese betekenisvolheid. *Potchefstroom, South Africa: North-West University. (online*) at http://www.puk.ac.za/opencms/export/PUK/html/fakulteite/natuur/skd/handleiding.html. Junie 2013.

Stodden, D. & Holfelder, B. (2013). Kein Kind bleibt zurück. *Zeitschrift für Sportpsychologie*, 20(1), 10-17.

Van Niekerk, C., Pienaar, A.E. & Coetzee, D. (2014). Aard van neuro-motoriese inperkings by 7- en 8-jarige leerders met leerhindernisse. *Suid-Afrikaanse Tydskrif vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning*, 36(1), 253-268.

Vuijk, J.P., Hartman, E, Mombang, R., Scherder, E., Visscher, C. & Visscher, C. (2011). Associations between academic and motor performance in a heterogeneous sample of children with learning disabilities. *Journal of Learning Disabilities*, 44(3), 276-282.

Wessels, Y., Pienaar, A.E. & Peens, A. (2009). Ontwikkelingskoödinasieversteuring (DCD) se verband met leerverwante probleme en ADHD by 6 tot 7-jarige kinders in Potchefstroom. *South African Journal for Research in Sport, Physical Education and Recreation*, 31(1), 139-149.

Wrotniak, B.H., Epstein, L.H., Dorn, J.M., Katherine, E.J. & Valerie, A.K. (2006). The relationship between motor proficiency and physical activity in children. *Pediatrics*, 118(6), 758-e1765, Des.