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RELATIONSHIP BETWEEN PHYSICAL FITNESS AND ACADEMIC PERFORMANCE IN SOUTH AFRICAN CHILDREN

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ABSTRACT

The aim of this study was to determine the relationship between physical fitness and academic achievement in an urban South African group of primary school children. A one-way cross-sectional design was used to assess physical fitness of children 9 to12 years (N=212) by means of the Fitnessgram, the Bruininks-Oseretsky Test of Motor Proficiency II, percentage body fat and Body Mass Index (BMI). Average end-of-the-year academic marks served as measurement of academic achievement. Relationships between the variables were determined by Spearman correlation coefficients and effect sizes, and a stepwise discriminant analysis. The results show a significant correlation between total strength scores and academic performance in the total group and between several fitness variables and academic performance in the female group. Significant correlations were found between specific strength tests and academic performance among older boys (12 years) and older girls (11 & 12 years). Several fitness parameters discriminated between high and low academic achievers. A positive relationship between physical fitness components and academic achievement was found with more significant correlations among girls than boys, as well as among older boys and girls.

Key words: Physical fitness; Academic achievement; Children; Obesity.

INTRODUCTION

Physical fitness has been associated with a variety of health benefits in both adults and children. Being physically fit reduces the risk of cardiovascular disease, type II diabetes and obesity (Hillman *et al*., 2008) and improves psychological variables, including depression, anxiety and stress (Eveland-Seyers *et al*., 2009). In addition to the health impact of physical fitness, a growing body of literature has linked physical fitness with improved brain function, cognition and academic achievement (Davis *et al*., 2007; Tomporowski *et al*., 2008; Shelton, 2009). Aerobic fitness has been associated with increased blood supply to the brain, increased brain mass and improved synaptic transfer in adults (Hillman *et al.*, 2008; Trudeau & Shephard, 2008). Recent studies have shifted the focus to the relationship between aerobic fitness and cognition in children. Hillman *et al.* (2005) found aerobic fitness to be positively associated with specific cognitive functioning associated with attention and working memory in preadolescent children, whereas Schott and Liebig (2007) found physical fitness to be a significant predictor of cognitive functioning in 8- to 16-year-old German children. Even in the short term, aerobic exercise has been shown to improve memory and learning state in children (Hillman *et al*., 2009), with these effects lasting up to 60 minutes (Blaydes, 2001).

The increased prevalence of children who are overweight and unfit has resulted in a growing field of research linking physical activity and physical fitness to academic achievement (Castelli *et al*., 2007). In the United States (US), several population-level cross-sectional studies have demonstrated positive associations between physical fitness and academic performance in 7- to 11-year-old children (Castelli *et al.*, 2007; Cottrell *et al*., 2007; Eveland-Seyers *et al*., 2009), as well as older children (Grissom, 2005; Chomitz *et al*., 2009). These studies used composite fitness indices, consistently reporting positive associations between aerobic fitness and academic achievement; although in some studies the effect decreased when socio-economic status was controlled for (Shelton, 2009). A few studies report positive associations between muscular fitness and academic test scores (Dwyer *et al.*, 2001; Eveland-Seyers *et al*., 2009) and some report associations between the number of fitness tests passed (including different fitness components) and academic test scores (Burton & Van Heest, 2007; Chomitz *et al*., 2009).

Similar investigations have been conducted in other developed countries. In a study involving a national sample of Australian children aged 7 to 15 years, Dwyer *et al*. (2001) found significant correlations between ratings of academic performance and the one-mile run, timed sit-up and timed push-up test, while Kim *et al*. (2003) report a significant association of physical fitness to academic performance in 11- to 17-year old Korean children (N=6463). In a national study in Iceland, Body Mass Index (BMI) and physical activity were two of the health components explaining up to 24% of the variance of academic achievement (Sigfudottir *et al.*, 2007).

Body composition, most commonly reported as BMI, is a health-related physical fitness component which has been shown to have a significant negative correlation with academic performance in children in several large-scale studies involving children of different ages (Datar *et al*., 2004; Castelli *et al.*, 2007; Cottrell *et al*., 2007; Kristjansson *et al*., 2009). However, BMI has been identified as a marker rather than a causal factor after including socio-economic and behavioural variables (Datar *et al*., 2004; Cottrell *et al*., 2007). In addition, overweight is associated with decreased cognitive functioning among school-age children and adolescents (Li *et al*., 2008; Cosgrove *et al*., 2009).

In accordance with international trends (Katzmarzyk *et al.*, 2008), studies show that urban South African children are growing increasingly sedentary, unfit and overweight (Kruger *et al*., 2005; Hurter & Pienaar, 2007). Governmental concerns regarding the health of South African school children played a major role in the reinstatement of Physical Education (PE) in the national school curriculum in 2002 (DoE, 2002). However, although it is widely recognised that PE provides an important avenue for the promotion of physical activity and physical fitness, recent studies show that PE is regarded as a 'low status' subject, which is often not offered in schools (Du Toit *et al*., 2007; Van Deventer, 2009). Investigating the relationship between physical fitness and academic performance will shed light on the potential role that PE has on learning abilities and academic outcomes of children, and may contribute to a new, positive perception of PE and its implementation in South African schools.

Only one recent study that addresses physical activity, physical fitness and academic outcomes in South African children, could be found in the research literature. Themane *et al.*

(2006) found no strong evidence for the positive association between physical activity, physical fitness and educational achievements in rural South African children (aged seven to 14 years), but attributed the results primarily to the unique educational problems and high levels of physical activity and physical fitness of the group. No evidence could be found that the relationship between physical fitness and academic achievement have ever been investigated in South African urban children. Therefore, this study aims to determine the relationship between physical fitness and academic achievement in an urban South African group of primary school children.

METHODOLOGY

The research design is a one-way cross-sectional design based on baseline measurements.

Research group

The research group consisted of Grade 4, 5 and 6 learners (N=212) from two urban primary schools in Potchefstroom, South Africa, representing a good distribution of socio-economic status, race and gender (n=94 boys and n=118 girls). The ages varied between 9 and 12 years (9 years [n=36]; 10 years [n=57]; 11 years [n=79]; 12 years [n=40]).

Measuring instruments

Physical fitness measurements

The physical abilities of the subjects (cardiovascular endurance, muscular strength, muscular endurance and flexibility) were determined using the Fitnessgram (Meredith & Welk, 1999) and the Bruininks-Oseretsky Test of Motor Proficiency II (Bruininks & Bruininks, 2005). The Fitnessgram consists of five components of which two, namely cardiovascular endurance and flexibility, were used in this study. Cardiovascular endurance was determined by using the *PACER* subtest where it was expected of the children to run back and forth over a distance of 20 meters at a predetermined pace which progressively increased in speed. Flexibility was determined by means of the *sit-and-reach* tests to the right and left. The Bruininks-Oseretsky test consists of eight subcomponents of which one, namely strength, was used for this study. The strength subcomponent consisted of five test items, namely standing long jump, knee push-ups, bent leg sit-ups, wall sitting and aeroplane lying. During the *standing long-jump* test, the subject must jump as far as possible from a standing position and the distance between the beginning and the nearest part of the body is measured and scored. The knee *push-up* requires that the subject stand on his/her hands and knees with the knees, hips and shoulders in line with one another. The upper body is lowered and lifted, while this shape is maintained and the number of correct attempts scored. With the bent leg *sit-up*, the subject lies on his/her back with the legs bent at a 45^o angle and must repeatedly attempt to lift and then lower the chest toward the knees. During the *wall-sitting* test, the subject stands with his/her back against the wall and moves downward until the legs are bent to 90^o at the hip and then attempt to maintain this position for 60 seconds. During the *lying aeroplane*, the subject must lie on his or her stomach and simultaneously lift both the arms and legs at the hip and shoulder joints off the ground and the time spent in this position is scored. The total of the various sub-items were calculated, after which it was converted to a scale, standard score and percentile for strength. Age equivalents, as well as descriptive categories, for the various sub-tests were calculated from this information.

Anthropometrical measurements

For the measurement of body composition as a component of physical fitness, body mass (kg) and stature (m), triceps, sub-scapular and medial calf skinfolds (mm) were measured by a trained researcher as prescribed by the "International Society for the Advancement of Kinanthropometry" (ISAK, 2001). Each skinfold was taken twice and the mean of the two measurements was obtained. The percentage body fat of the subjects was gender specifically calculated with the aid of the triceps and the calf skinfolds (Slaughter *et al.*, 1988). The BMI of each subject was calculated using the following formula: body mass in kg / stature (m)^2 (Cole *et al.*, 2000).

Measurement of academic performance

The average of the end-of-the-year academic marks, as recorded in school schedules and children's report cards according to the prescriptions of the National Department of Education (DoE, 2005) for learners in the Intermediate Phase (Grade 4, 5 and 6), was used as a measure of academic achievement. This mark represents the average of percentages achieved by the learner in each of the eight learning areas (subjects) in the Intermediate Phase, namely Languages, Mathematics, Natural Sciences, Technology, Social Sciences, Art and Culture, Life Orientation and Economic and Management Sciences (DoE, 2002). The National Curriculum Statement (NCS) standardises the recording and reporting of learner achievement in each learning area by means of very specific specifications and requirements with regard to the number and types of assessment tasks, including end-of-the-year examinations (DoE, 2005).

Research procedure

The Ethics Committee of the North-West University granted ethical permission for this study (No. 07M07). The headmasters of the schools were then approached to obtain permission for the study after which informed consent forms were distributed to all Grade 4, 5 and 6 learners of the schools a week before the study commenced. The parents of all learners consented to participation in the study.

Statistical analysis

The data was analysed using the Statistica software package (Statsoft, 2008) for descriptive statistics (mean, standard deviation [SD], maximum and minimum values), while the relationships between the variables were determined by Spearman correlation coefficients. To determine the practical significance of correlations, correlation coefficients were used as effect sizes according to the guidelines of Cohen (1988) and Steyn (2006). A correlation coefficient of 0.1 represents a small effect, 0.2 a medium effect and 0.5 a large effect (Cohen, 1988). Finally, a stepwise discriminant analysis determined which physical fitness parameters discriminated between high academic achievers and low academic achievers at a significance level of 0.3, using *Statistical Analysis System* (SAS Institute Inc., 2005).

RESULTS

Descriptive statistics for the variables used in this study, are presented in Table 1.

TABLE 1: **DESCRIPTIVE STATISTICS OF STUDY VARIABLES**

	Boys (n=94)				**Girls** (n=118)			
Variable	M	SD	Min	Max	M	SD	Min	Max
Age (years)	10.8	1.0	9.0	12.0	10.6	1.1	9.0	12.0
Academic mark (%)	58.7	14.2	29.0	87.9	63.4	13.7	35.0	93.9
BMI	18.9	4.3	13.7	39.9	18.9	3.9	13.6	30.4
Body fat %	19.1	9.4	6.2	59.1	21.8	6.7	11.7	42.3
PACER (laps)	31.5	17.1	5.0	69.0	20.8	11.4	5.0	58.0
Sit & Reach R (cm)	24.1	7.1	2.0	40.5	24.5	7.1	0.0	37.0
Sit & Reach L (cm)	23.3	7.1	2.0	41.0	24.3	7.2	0.0	40.0
Long jump (cm)	123.3	23.3	13.2	173.8	111.5	22.5	8.1	157.2
Knee push-ups	16.4	4.7	3.0	28.0	12.3	7.3	1.0	70.0
Sit-ups	22.9	5.9	5.0	35.0	19.3	5.1	0	32.0
Wall sitting (sec)	40.1	17.4	5.0	60.0	42.8	17.6	5.0	60.0
Aeroplane (sec)	50.0	17.0	5.9	60.0	46.2	17.9	2.0	60.0
Strength total	58.7	21.5	7.0	90.0	55.8	22.1	14.0	95.0

	Total group (N=212)			
Variable	M	SD	Min	Max
Age (years)	10.7	1.0	9.0	12.0
Academic mark (%)	61.3	14.1	29.0	93.9
BMI	18.9	4.1	13.6	39.9
Body fat %	20.6	8.3	6.2	59.1
PACER (laps)	25.5	15.1	5.0	69.0
Sit & Reach R (cm)	24.3	7.1	0	40.5
Sit & Reach L (cm)	23.8	7.2	0	41.0
St. Long jump (cm)	117.0	23.6	8.1	173.8
Knee push-ups	14.1	6.6	1.0	70.0
Sit-ups	20.9	5.7	0	35.0
Wall sitting (sec)	41.6	17.5	5.0	60.0
Aeroplane (sec)	47.9	17.6	2.0	60.0
Strength total	57.1	21.8	7.0	95.0

BMI = Body Mass Index Strength total = Percentile for total strength sub-component

From this it would appear that girls achieved better academic marks than boys, although the difference was not necessarily statistically significant. The mean percentage body fat of girls (22%) appeared to be higher than that of boys (19%), even though BMI-values of the boys and girls were similar (19). Girls scored higher than boys in the academic and flexibility measurements, while boys were superior in the aerobic and strength tests, except for the wall sitting test where the female group showed a slight advantage. The total strength scores for the total group, as well as the male and female groups, showed that the subjects fell on the

56th to 59th percentile for their ages, indicating average to slightly above average muscular fitness.

Table 2 displays the correlation coefficient of academic measurements with physical fitness parameters in the overall sample and in the male and female groups. The analysis showed that the results of the sit-up, wall sitting and aeroplane lying tests exhibited significant positive correlations ($p<0.05$) with academic achievement in the total group, although these correlations were of small practical significance.

TABLE 2: **CORRELATION COEFFICIENTS OF ACADEMIC MEASUREMENTS WITH PHYSICAL FITNESS PARAMETERS IN THE OVERALL SAMPLE AND AMONG GENDERS**

Variable	**Total group** (N=212)	**Boys** (n=94)	**Girls** (n=118)
BMI	-0.07	-0.06	-0.08
Body fat %	-0.01	-0.09	***-0.21**
PACER	0.09	0.12	***0.21**
Sit & Reach R	-0.04	-0.06	-0.03
Sit & Reach L	-0.09	-0.10	-0.10
Standing long-jump	0.06	0.03	***0.18**
Knee push-ups	0.12	0.07	***0.25**
Sit-ups	***0.10**	***0.14**	0.17
Wall sitting	***0.25**	0.03	***0.42**
Aeroplane lying	***0.21**	0.14	***0.31**
Strength total	***0.27**	***0.23**	***0.35**

Body fat % = Body fat percentage BMI = Body Mass Index * = $p<0.05$

The total strength score of the over-all group showed a positive correlation ($p<0.05$) with medium practical significance. In the boys group, only the results of the sit-up test and the total strength test were positively related ($p<0.05$) to academic performance (small practical effect). Percentage body fat exhibited a significant negative correlation ($p<0.05$) with academic performance (small practical effect) among the girls.

With the exception of the sit-up test, aerobic fitness and all the strength tests, results showed significantly positive correlations with academic performance among the girls. Of these, positive correlations with a medium effect were found between muscular endurance as measured by the tests, wall sitting and aeroplane lying, and overall muscular fitness as indicated by the total strength percentile and academic performance.

A further analysis of the possible correlations between academic and physical fitness variables with regard to categories of age and gender was also performed (Table 3). Among the 9-, 10- and 11-year-old boys, no physical fitness parameters showed any significant correlations with academic performance marks. The only significant correlations among the boys were found in the 12-year-old group, where the standing long-jump and sit-ups sub-items of the strength component, as well as the total strength score showed correlations of large practical significance.

Percentage body fat was negatively related to academic marks in the 11-year-old girls (medium practical effect). In the 11- and 12-year-old female groups, aerobic fitness exhibited positive correlations with academic marks, of medium and large effects. Only one strength sub-item (knee push-ups) showed a significant correlation of medium practical significance to academic marks in the 10-year-old female group, whereas the results of several strength tests (sit-ups in the 11-year olds, wall sitting in the 11-and 12-year-olds, aeroplane lying in the 12-year-olds, and total strength scores in both the 11- and-12year-old groups) showed correlations of medium to large significance ($p<0.05$).

TABLE 3: **CORRELATION COEFFICIENTS OF ACADEMIC WITH PHYSICAL FITNESS PARAMETERS ACCORDING TO GENDER AND AGE**

	Boys				**Girls**			
Variable	**9 yrs** (n=13)	**10 yrs** (n=27)	**11 yrs** (n=35)	**12 yrs** (n=19)	**9 yrs** (n=23)	**10 yrs** (n=30)	**11 yrs** (n=44)	**12 yrs** (n=21)
BMI	0.26	-0.06	-0.07	-0.15	0.08	0.09	-0.06	-0.06
Body fat %	-0.58	-0.08	-0.03	-0.30	0.02	0.06	***-0.34**	-0.17
PACER	0.12	0.22	-0.02	0.40	0.30	-0.24	***0.38**	***0.63**
Sit & Reach R	-0.34	-0.21	-0.08	0.23	0.17	-0.23	-0.05	0.27
Sit & Reach L	-0.31	-0.15	-0.15	0.10	0.05	-0.23	-0.08	0.20
Stand. long-jump	0.12	-0.17	0.13	***0.50**	0.31	0.01	0.29	0.42
Knee push-ups	0.38	-0.24	0.11	0.45	0.07	***0.38**	0.29	***0.62**
Sit-ups	0.30	0.05	0.32	***0.49**	0.00	0.31	***0.33**	0.30
Wall sitting	0.23	-0.09	0.08	0.16	0.34	0.28	***0.57**	***0.54**
Aeroplane lying	-0.04	-0.14	0.27	0.30	0.24	0.20	0.27	***0.57**
Strength total	0.48	-0.12	0.25	***0.51**	0.25	0.28	***0.44**	***0.62**

* = $p<0.05$

To determine which physical fitness parameters discriminated between participants with high academic marks and those with low marks, a stepwise discriminant analysis was done. For this purpose, the top 40% (n=81) and the lower 40% (n=82) of academic achievers in the group were identified as high achievers and low achievers. According to this analysis (Table 4), the physical fitness parameters of wall sitting, sit-and-reach (left) and sit-ups, in that order, discriminated most between high and low academic achievers. According to Steyn (2006), the factors shown to discriminate between groups in a step-wise discriminant analysis do not discriminate separately but together and may be inter-correlated. However, none of these variables discriminated statistically significantly at $p<0.05$.

TABLE 4: **PREDICTOR PHYSICAL FITNESS VARIABLES IN ACADEMIC ACHIEVEMENT: STEPWISE DISCRIMINANT ANALYSIS**

Step	Number in	Entered	F-value	Wilks' Lambda
1	1	Wall sitting	12.11	0.93
2	2	Sit-and-reach L	1.23	0.92
3	3	Sit-ups	1.45	0.91

Cross-validation of groups were done to establish predictive validity, using non-linear discriminant function (Table 5) and showing that 46% of the total group were correctly classified into the lower achievers group using the physical fitness parameters, while 80% were correctly classified into the high achievers group. These results do not imply that physical fitness parameters can be used to predict academic achievement, but show a tendency for high academic achievers to be physically fitter.

TABLE 5: **OBSERVATIONS CLASSIFIED INTO CORRECT GROUPS ACCORDING TO CROSS-VALIDATION OF LOW AND HIGH ACHIEVERS**

Group	Classified as low achiever	Classified as high achiever	Total
Low achievers	31 45.6%	37 54.4%	68 100%
High achievers	19 20.0%	76 80.0%	95 100%
Total	50 30.7%	113 69.3%	163 100%

Considering the significance of the classifications above, the observed hit rate (Ho), the chance hit rate (He) and the group overlap index (*I*), were calculated according to the guidelines of Steyn (2006). According to Steyn (2006), when calculating the group overlap index in comparing two populations, $I<0.1$ can be interpreted as an index of small practical effect, $0.15<I<0.25$ as one of medium effect, and $I>0.3$ as a large effect. The index of 0.29 found in this study (Table 6) thus shows that the academic achievement classification in relation to these physical fitness parameters showed practical significance of a medium to large effect. This result confirmed that physical fitness parameters distinguished between low and high academic achievers in this study.

TABLE 6: **GROUP OVERLAP INDEX**

Ho Observed hit rate	**He** Chance hit rate	**n**	***I*** Group overlap index
0.66	0.51	163	0.29

DISCUSSION

The mean BMI and percentage body fat of the total group of participants can be classified as "normal", according to the cut-off points for growing children of Cole *et al*. (2000). In the total group of subjects, the mean PACER-test results (Meredith & Welk, 1999), as well as the mean total strength scores (57th percentile) indicated that the aerobic and muscle fitness of the total group could be considered average to slightly above average. Although the statistical significance of differences between genders with regard to physical fitness components was not included in the aim of this study, it is worth noting that the differences between boys and girls with regard to percentage body fat (girls usually show higher percentage body fat), aerobic capacity (boys show greater aerobic capacity), flexibility (girls are usually more flexible) and strength (boys are usually stronger) appeared to be similar to those recorded in literature for these age groups (Pienaar, 2009).

The significant correlation between percentage body fat and academic performance in the over-all female group, agrees with results found in the study of Datar and Strum (2006), where overweight status had an adverse effect on academic outcomes among girls, but not among boys. Furthermore, significant differences between boys and girls with regard to correlations between aerobic fitness and academic performance were found in the studies of Carlson *et al*. (2008) and Eveland-Sayers *et al*. (2009). However, in the current study percentage body fat was not shown to be one of the factors discriminating between low and high academic achievers, in contrast to the specific strength tests of wall sitting and sit-ups, as well as the sit-and-reach flexibility test (left). Steyn (2006) proposed that some discriminating factors might be interrelated, and should be considered together as fitness variables and not as separate factors.

Significant correlations were found between specific strength tests and academic performance, and more so among older boys (12-year-olds) and older girls (11- and 12-year-olds). Furthermore, the specific period of 10½ to 11 years of age in girls is generally considered to be the end of a growth spurt and the onset of puberty (Pienaar, 2009). Santrock (2008) postulates that the many physiological and psychological changes associated with this developmental stage in a child's life, significantly influence both physical and cognitive variables. As boys usually experience a growth spurt from the age of 11 until the onset of puberty around the age of 14, the link between strength and academic performance found in the 12-year-old group might warrant further research investigating the relationship between developmental stages such as increased growth rate, strength and academic performance in boys. Additionally, the association of academic performance with fitness components in older girls and boys appeared to exhibit a tendency to increase in significance with an increase in age. This emerging tendency could be related to the tendency of South African urban children, especially girls, to become increasingly sedentary when they approach and enter adolescence (Amosun *et al*., 2007), possibly as a result of increased academic pressure.

While the research literature cannot yet fully explain why fit learners may perform better in academic parameters, Chomitz *et al*. (2009) proposed that, in addition to the proven effects of aerobic exercise and fitness on brain function and cognition, the relationship between fitness and academic achievement may reflect the overall achievement orientation of motivated learners. These authors also suggest that a learner's physical fitness may reflect better overall health, which has been shown to contribute to academic performance. Cottrell *et al*. (2007) agrees that the role players in academic performance are complicated and that children's academic test scores are influenced by a combination of factors including fitness index, gender, cardiovascular risk factors and socio-economic status.

SUMMARY AND CONCLUSION

The results of this study suggest a positive relationship between physical fitness components and academic achievement in a group of South African primary school children, with more significant correlations found among girls than boys, and among older boys and girls.

Based on these findings, as well as factors such as national pressure to increase academic achievement in South African schools, and the increasing prevalence of overweight and obesity and physical inactivity in South African children, advocating the enhancement of physical fitness levels of children by means of maximum educator support and promotion of school PE, is warranted. Additionally, future research into the mechanisms of the physical fitness/academic performance-relationship in pubertal and adolescent boys and girls, will lead to a better understanding of the potential contribution of PE to academic enhancement among older children.

In conclusion, the results of this study should be interpreted with the following limiting factors in mind. Firstly, the sample size was relatively small which made generalisation of the results difficult. Secondly, a factor which was not controlled for in this study, the socio-economic status of learners, has been shown to influence the association of physical fitness with academic performance (Cottrell *et al*., 2007) and could therefore have had an influence on the results. Thirdly, several studies found that physical fitness shows stronger associations with some subjects than others (Chomitz *et al*., 2009; Eveland-Seyers *et al*., 2009). More prominent results might have been obtained if additional measures of academic performance in different learning areas or subjects had been used instead of only one overall academic mark. Notwithstanding these limitations, the study offered new and important information that can be used by educators, parents and policy makers in South Africa to advocate and promote physical activity and physical fitness among primary school children.

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