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Physically active academic lessons

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CHAPTER 2

Physical fitness and academic performance in primary school children with and without a social disadvantage²

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ABSTRACT

This study examined the differences between children with a low socioeconomic status [socially disadvantaged children (SDC)] and children without this disadvantage (non-SDC) on physical fitness and academic performance. In addition, this study determined the association between physical fitness and academic performance, and investigated the possible moderator effect of SDC. Data on 544 children were collected and analyzed (130 SDC, 414 non-SDC, mean age = 8.0 ± 0.7). Physical fitness was measured with tests for cardiovascular and muscular fitness. Academic performance was evaluated using scores on mathematics, spelling and reading. SDC did not differ on physical fitness, compared with non-SDC, but scored significantly lower on academic performance. In the total group, multilevel analysis showed positive associations between cardiovascular fitness and mathematics [$\beta = 0.23$], and between cardiovascular fitness and spelling [$\beta = 0.16$], but not with reading. No associations were found between muscular fitness and academic performance. A significant interaction effect between SDC and cardiovascular fitness was found for spelling. To conclude, results showed a specific link between cardiovascular fitness and mathematics, regardless of socioeconomic status. SDC did moderate the relationship between cardiovascular fitness and spelling.

INTRODUCTION

Children with a low socioeconomic status [socially disadvantaged children (SDC)] are more at risk of overweight (Danielzik et al., 2004) and have a higher prevalence of health threatening conditions associated with physical inactivity, such as osteoarthritis, hypertension or chronic diseases (Adler & Ostrove, 2006). Because physical fitness is generally considered to be the ability to perform physical activity (Ortega et al., 2008), it is one of the most important health marker, as well as predictor of these health threatening conditions (Malina, 2001). It is therefore hypothesized that SDC have relatively low fitness levels compared with children without a social disadvantage (non-SDC). In addition to the lower health status, a medium-to-strong association exists between socioeconomic status and academic performance, indicating that SDC has also been linked with lower academic performance (Castelli et al., 2007; Chomitz et al., 2008; O'Dea & Mugridge, 2012; Sirin, 2005).

It is possible that low physical fitness levels and low academic performance co-occur in preadolescent children. In preadolescent children, a small number of studies reported a global positive association between physical fitness and academic performance (Castelli et al., 2007; Chomitz et al., 2008; Eveland-Sayers et al., 2009). The studies were inconclusive regarding the possible specific association. A cross-sectional study investigated the association between physical fitness and academic performance among third- and fifth-grade children, while focusing on different domains of physical fitness (cardiovascular and muscular fitness) and academic performance (mathematics and reading) (Castelli et al., 2007). Only cardiovascular fitness was positively related to both mathematics and reading. Others found that both cardiovascular and muscular fitness were associated with mathematics, but not with reading (Eveland-Sayers et al., 2009). In sum, several cross-sectional studies described the association between domains of physical fitness and academic performance. Given the mixed findings, it remains unclear whether a general or specific association exists between the different domains of physical fitness and academic performance. In addition, it is unknown whether or not SDC moderates these relations.

Several mechanisms have been proposed that might explain the positive association between physical fitness and academic performance. There is evidence that through regular participation in physical exercise of moderate (Ruiz et al., 2006) or vigorous intensity (Adler & Ostrove, 2006; Kwak et al., 2009), changes in cardiovascular fitness occur, leading to short and long-term effects on cognitive performance. Regarding the short-term effects, immediate changes in concentration levels of neurotransmitters follow after exercise. For example, exercise increases concentrations of the brain-derived neurotrophic factor (BDNF), which stimulates learning and memory (Dishman et al., 2006; Winter et al., 2007). On the long term, chronic exercise will lead to morphological brain changes, caused by upregulation of growth factors which are responsible for synaptic plasticity and neurogenesis (Dishman et al., 2006). In addition, some studies suggest that the cognitive demands that underlie exercise might improve cognitive performance (Best, 2010; Sibley & Etnier, 2003). For example, team sport games or physical education contains several cognitive challenging demands, such as setting goals, making

decisions, employing different strategies and working together with teammates. The cognitive skills learned during these activities are assumed to benefit academic performance (Taras, 2005). To summarize, regular participation in exercise will lead to morphological brain changes, which benefit academic performance. Previous literature showed that lower physical fitness and lower academic performance is expected in SDC, compared with non-SDC, which is an indication that socioeconomic status is related with physical fitness and academic performance. This suggests that the association between physical fitness and academic performance can also be influenced by the socioeconomic status.

Accordingly, the first aim of this study was to examine the differences between SDC and non-SDC on physical fitness and academic performance. The second aim was to investigate the associations between different domains of physical fitness (cardiovascular and muscular fitness) and academic performance (mathematics, reading and spelling). The third aim was to examine whether SDC moderates the relation between physical fitness and academic performance.

METHODS

Participants

We obtained data from 544 primary school children of the second and third grade. All children were enrolled across 16 schools in the Northern part of the Netherlands. Children were included if they were healthy, i.e. not suffering from any physical illness or injury at the time of testing. In Table 2.1, the descriptive characteristics of the study population are shown. The study population included 286 girls and 258 boys, with 51% second-grade children ($n = 277$) and 49% third-grade children ($n = 267$). The children's mean age was 8.0 (SD = 0.7; range 7–10 years). Children were categorized in SDC or non-SDC based on the education of the person(s) who is (or are) responsible for the daily care. Data about the education were retrieved from the personal school file of each child. Children for whom both parents, or the person(s) responsible for daily care, completed less than 3 years of the secondary school were classified as SDC ($n = 130$) (Ministry of Education, Culture and Science, 2006). All other children were classified as non-SDC ($n = 414$). In addition to the SDC classification, the person responsible for the daily care (caregiver) was asked about the highest level of educational attainment, using a questionnaire. The response rate was 66.0% ($n = 359$). In this subsample, it appeared that for the caregiver of SDC 29.1% ($n = 25$) had no diploma, 51.2% ($n = 44$) completed secondary education and 19.8% ($n = 17$) completed middle-level applied education. For the caregiver of the non-SDC 3.3% ($n = 9$) had no diploma, 21.2% ($n = 58$) completed secondary education, 50.2% ($n = 137$) completed middle-level applied education, 19.4% ($n = 53$) completed higher professional education and 5.9% ($n = 16$) completed university. Educational levels of the caregiver of the SDC were significantly lower than those of the caregiver of the non-SDC [$U = 4088.0$, $p < 0.01$], indicating that the SDC classification was justified. The SDC classification was used in the remaining part of the study, because using the highest level of educational attainment as a measure of socioeconomic status would have resulted in considerable data loss.

Overweight and obesity were defined according to the reference values for BMI in children (Cole et al., 2000). SDC and non-SDC were comparable on all descriptive characteristics, apart from age. SDCs were significantly older compared with the non-SDCs [$t = -4.1$, $p < 0.01$]. Informed consent was obtained for all children, and all procedures were approved by the institutional Ethics Committee of the Center for Human Movement Sciences of the University Medical Center Groningen, University of Groningen.

Measurement instruments

Physical fitness was evaluated with five items of the Eurofit physical fitness test battery (Adam et al., 1988). The standardized and validated Eurofit test battery has been designed for assessment of health-related fitness in both children as well as adults (Adam et al., 1988). The test battery was administered by instructed researchers to ensure consistency in the test administration. The 20 m endurance shuttle run (Riddoch, 1990) and 10 × 5 m shuttle run were admin-

Table 2.1 Descriptive characteristics of the study population.

	SDC (n = 130)	non-SDC (n = 414)	<i>p</i> value
Age, years (sd)	8.3 (0.7)	8.0 (0.7)	< 0.010 ^a
BMI, kg/m ² (sd)	17.0 (2.7)	16.8 (2.6)	0.367 ^a
- Overweight, n (%) ^c	25 (19)	61 (15)	0.446 ^b
- Obesity, n (%) ^c	7 (5)	27 (7)	
Gender, n boys (%)	62 (48)	196 (47)	0.945 ^b
Grade			
- Second, n (%)	63 (48)	214 (52)	0.521 ^b
- Third, n (%)	67 (52)	200 (48)	

SDC = socially disadvantaged children, Non-SDC = children without a social disadvantage. ^aIndependent t-test. ^bNon-parametric Chi-square test. ^cAccording to the reference values by Cole et al. (2000).

istered for measuring cardiovascular fitness. Standing broad jump (explosive strength), sit-ups (abdominal muscle endurance) and handgrip strength (static strength) were administered for measuring muscular fitness. The test battery was assessed during two regular scheduled physical education lessons on each school at the start of the school year, with approximately 1 week between the two lessons. During one lesson, the children were familiarized with the 10 × 5 m shuttle run, standing broad jump, sit-ups and handgrip strength and were given two trials for each test. The best performance was used for further analysis. During the other lesson, the 20 m endurance shuttle run was assessed and body composition (BMI) was obtained through height and weight measures. One trial was given for the 20 m endurance shuttle run.

Academic performance was evaluated with scores on mathematics and two domains of language, namely spelling and reading. For each child, the ability scores on spelling and mathematics were retrieved from the so-called child academic monitoring system. This is a standardized norm referenced test battery that is administered twice a year by most primary schools in The Netherlands. The mathematics test is an individually performed pencil and paper or digital task which consists of three subdomains, namely geometry, time and money; number sense and computation; and algebra. The reliability [*r* varied from 0.91 to 0.96], the construct validity and the content validity of the mathematics test are good (Janssen et al., 2010). The spelling test consists of two tasks. During the first task, the teacher has to read out a sentence, and repeat a given word within this sentence. The child has to write down this repeated word correctly. The second task is to recognize given words that are spelled incorrectly (de Wijs et al., 2010). The reliability [*r* varied from 0.87 to 0.92], the construct validity and the content validity of the spelling test are good (de Wijs et al., 2010). The mathematics and spelling tests were administered at the end of the previous school year. Reading was assessed with the 1-min reading test, in which the child had to read out loud as many words as possible within 1 min (Brus & Voeten, 1973). After 1 min, the test was repeated with a different set of words. The test was administered by instructed researchers to ensure consistency in the test administration. The score was calculated as the total number of words read correctly and ranges from 0 to 232. The test has been developed for measuring technical reading skills in children from second to sixth grade. Test

retest reliability [r varied from 0.89 to 0.92] and construct validity [r varied from 0.78 to 0.86] of the 1-min reading test are good (Brus & Voeten, 1973). The 1-min reading test is not part of the standardized norm-referenced test battery. The test was administered by instructed researchers at the start of the school year. Although mathematics, spelling and reading are important domains of academic performance, it should be acknowledged that academic performance represents more than these three domains. Therefore, reference to academic performance in this study is limited to the scores on mathematics, spelling and reading.

Statistical analysis

Statistical analysis was conducted using SPSS for Windows, version 20.0. For evaluating the differences between SDC and non-SDC, analyses of covariance (ANCOVA) were conducted. The first ANCOVA included standing broad jump as the dependent variable and the SDC classification (coded as 0 = non-SDC, 1 = SDC) as the independent variable. Age, grade (coded as 0 = second grade, 1 = third grade) and gender (coded as 0 = girls, 1 = boys) were used as covariates. Because SDCs were significantly older compared with non-SDCs, both grade and age were added as covariates to control for the educational experience. The same statistical analysis was repeated for the other domains of physical fitness (sit ups, handgrip strength, 10 × 5 m shuttle run and 20 m endurance shuttle run) and for the domains of academic performance (mathematics, spelling and reading) as dependent variables. To take into account the unbalanced design, Type III sums of squares were used (Field, 2005) and effect size correlations were calculated in accordance with Rosnow et al. (2000). An effect size correlation between 0.10 and 0.30 was considered small, 0.30–0.50 moderate and above 0.50 large (Rosnow et al., 2000).

A principal component analysis was conducted to compute a Bartlett factor score for muscular fitness, summing the raw scores of standing broad jump, situps and handgrip strength and for cardiovascular fitness, summing the raw scores of the 10 × 5 m shuttle run and 20 m endurance shuttle run. The advantage of Bartlett's approach is that it produces a score which is uncorrelated with scores of other factors (Grice & Harris, 1998). Only items with loading values above 0.300 for the intended factor were included for further analysis.

To account for the common experience the children share within each school (Telford et al., 2012) and within each class, multilevel analyses were conducted (MLwiN, version 2.23). First, the raw scores of mathematics, spelling and reading performance were transformed into z-scores. The first multilevel analysis included mathematics as dependent variable. SDC, cardiovascular fitness, muscular fitness and the interaction effects between SDC and both cardiovascular and muscular fitness were used as possible predictors. Grade and gender were included as covariates. Class and school were added in the statistical model as, respectively, levels 2 and 3 and a random intercept for each school and class was considered. The same statistical analysis was repeated for spelling and reading as dependent variables. The deviances of the three models (mathematics, spelling and reading) were compared with the deviances of the covariates models, which included only the covariates (Snijders & Bosker, 2011). The final model included the covariates and the possible predictors. The interactions between SDC and

both domains of physical fitness were entered in the models, investigating if SDC moderated the relationships between physical fitness and mathematics, spelling or reading performance. Effect sizes for each predictor of the multilevel models were calculated using the explained variance (R^2). The explained variance was calculated by comparing the total variance of the model including the predictor, with the total variance of the intercept only model (Snijders & Bosker, 2011). Statistical significance was adopted for all tests when $p < 0.05$.

RESULTS

There were no significant differences in physical fitness between the SDC and non-SDC (Table 2.2). Non-SDC scored significantly higher on mathematics [$p < 0.01$], spelling [$p < 0.01$] and reading [$p < 0.05$], compared with the SDC.

Table 2.2 Comparison of the SDC and non-SDC on the estimated mean score and standard errors of physical fitness and academic performance, while controlling for age, grade and gender.

	SDC (n = 130) Estimated mean (SE)	non-SDC (n = 414) Estimated mean (SE)	<i>p</i> value ^c	<i>ES</i>
Physical fitness:				
- Standing broad jump, cm ^a	122.9 (1.7)	122.2 (1.0)	0.715	0.016
- Sit-ups, n ^a	14.6 (0.4)	14.3 (0.2)	0.385	0.037
- Handgrip strength, kg ^a	13.6 (0.3)	13.1 (0.2)	0.118	0.067
- 10 × 5 m shuttle run, s ^b	24.5 (0.2)	24.3 (0.1)	0.338	0.041
- 20 m endurance shuttle run, stages ^a	3.9 (0.1)	4.0 (0.2)	0.772	0.012
Academic performance:				
- Mathematics, score ^a	47.7 (1.3)	53.8 (0.7)	< 0.010	0.170
- Spelling, score ^a	117.3 (0.6)	119.2 (0.3)	< 0.010	0.127
- Reading, score ^a	78.4 (2.4)	84.4 (1.3)	< 0.050	0.092

ES = effect size.

^aThe better the performance, the higher the score. ^bThe better the performance, the lower the score. ^cANCOVA (statistically adjusted for age, grade and gender).

The physical fitness items standing broad jump, sit-ups and handgrip strength loaded high on factor 1, representing muscular fitness (Table 2.3). The items 10 × 5 m shuttle run and 20 m endurance shuttle run loaded high on factor 2, representing cardiovascular fitness. All items loaded high on the intended factor (above 0.300) and were therefore included for further analysis.

Table 2.3 Descriptive characteristics of the study population.

	Factor 1	Factor 2
Physical fitness:		
1. Standing broad jump		0.513
2. Sit-ups		0.440
3. Handgrip strength		0.910
4. 10 × 5 m shuttle run	-0.773	
5. 20 m endurance shuttle run	0.849	
Eigenvalue	2.343	0.958
Cumulative variance explained (%)	47	66

The outcome of the multilevel models predicting the performance on mathematics, spelling and reading can be found in Table 2.4. SDC scored lower on mathematics, compared with non-SDC [$\beta = -0.36, p < 0.01, R^2 = 0.02$]. Cardiovascular fitness was positively associated with mathematics [$\beta = 0.23, p < 0.01, R^2 = 0.06$], indicating that a higher cardiovascular fitness was associated with higher scores on mathematics. No significant interaction effect was found between SDC and cardiovascular fitness, indicating that SDC did not moderate the association. SDC scored also lower on spelling [$\beta = -0.30, p < 0.01, R^2 = 0.01$]. A positive association was found between cardiovascular fitness and spelling performance [$\beta = 0.16, p < 0.05, R^2 = 0.01$]. However, a negative interaction effect was present between SDC and cardiovascular fitness [$\beta = -0.30, p < 0.01, R^2 = 0.00$], indicating that the association between cardiovascular fitness and spelling performance was moderated by SDC and therefore depends on whether the child has a social disadvantage or not. The interaction effect demonstrates that the positive association between cardiovascular fitness and spelling was only found in non-SDC. For reading, SDC scored significantly lower compared with non-SDC [$\beta = -0.24, p < 0.01, R^2 = 0.01$]. Both cardiovascular and muscular fitness were no significant predictors in the model, indicating that there was no association between physical fitness and reading performance.

Table 2.4 Standardized regression coefficients (β) and standard errors (SE) for each factor predicting mathematics, spelling and reading performance.

Fixed effects	Mathematics				Spelling				Reading			
	β	SE	<i>p</i> value	R^2	β	SE	<i>p</i> value	R^2	β	SE	<i>p</i> value	R^2
Random intercept	-0.50	0.08	< 0.01		-0.37	0.10	< 0.01		-0.42	0.08	< 0.01	
Grade ^a	1.04	0.10	< 0.01	0.28	1.14	0.12	< 0.01	0.32	1.02	0.09	< 0.01	0.24
Gender ^b	0.17	0.07	< 0.05	0.01	-0.24	0.07	< 0.01	0.02	-0.05	0.08	0.540	0.00
SDC ^c	-0.36	0.08	< 0.01	0.02	-0.30	0.08	< 0.01	0.01	-0.24	0.09	< 0.01	0.01
Cardiovascular fitness	0.23	0.04	< 0.01	0.06	0.16	0.04	< 0.01	0.01	0.05	0.04	0.256	0.00
Muscular fitness	-0.05	0.04	0.218	0.00	-0.05	0.04	0.197	0.00	-0.03	0.05	0.529	0.00
SDC*Cardiovascular	-0.12	0.08	0.112	0.01	-0.30	0.07	< 0.01	0.00	-0.15	0.08	0.064	0.00
SDC*Muscular	0.12	0.08	0.128	0.00	0.02	0.08	0.800	0.00	-0.09	0.08	0.290	0.00
Deviance	1291.54				1262.61				1368.02			
Deviance covariates model	1344.11				1299.66				1384.05			

^aCoded as 0 for second grade, 1 for third grade. ^bCoded as 0 for girls, 1 for boys. ^cSDC = socially disadvantaged children, Coded as 0 for non-SDC, 1 for SDC.

DISCUSSION

This study showed that SDC scored significantly lower on all domains of academic performance in comparison to non-SDC. No significant differences were found for physical fitness. In the total population, cardiovascular fitness was positively associated with mathematics and spelling, but not with reading. Muscular fitness was not associated with academic performance. After taking SDC into account, the association between cardiovascular fitness and mathematics persisted, indicating that SDC did not moderate this relationship. However, SDC did moderate the relationship between cardiovascular fitness and spelling, which indicated that the positive association between cardiovascular fitness and spelling was only found in non-SDC and not in SDC.

Although the strength of the associations was small, non-SDC outperformed SDC on mathematics, spelling and reading, which is in accordance with previous literature (Chomitz et al., 2008; O’Dea & Mugridge, 2012). However, no differences on the domains of physical fitness between SDC and non-SDC were found. According to the authors’ knowledge, no previous literature is available on the association between socioeconomic status and physical fitness in preadolescent children in developed countries. Previous literature did show that SDC are less likely to be physically active (Woodfield et al., 2002), which may influence children’s physical fitness negatively. In this study, both groups had relative low fitness scores on standing broad jump, sit-ups and 10 × 5 m shuttle run compared to a large sample of 8-year-old Latvian children (Sauka et al., 2011). For physical fitness, the school or exercise possibilities in the neighborhood of the children might be a stronger predictor than having a social disadvantage (Ebbeling et al., 2002; Tappe et al., 2013).

A weak but significant association was found between cardiovascular fitness and multiple domains of academic performance explaining between 1 and 6% of the variance, whereas muscular fitness was not related with any of the domains. In accordance with these results, another study showed that only cardiovascular fitness was positively related with academic performance in preadolescent children (8–11 years), and not muscular fitness (Castelli et al., 2007). This specific positive association extends the evidence for the cardiovascular fitness hypothesis (North et al., 1990). This hypothesis states that through regular participation in physical exercise of moderate (Ruiz et al., 2006) or vigorous intensity (Kwak et al., 2009; Ortega et al., 2008), changes in cardiovascular fitness occur, which will lead to increased cerebral blood flow. On the long term, chronic exercise will lead to upregulation of growth factors, responsible for synaptic plasticity and neurogenesis (Winter et al., 2007). For example, exercise increases concentrations of the BDNF, which stimulates learning and memory (Dishman et al., 2006).

Small positive associations between cardiovascular fitness and the domains mathematics and spelling were found in the total population but not between cardiovascular fitness and reading. These results are partly in accordance with other cross-sectional studies. A stronger association was found between total physical fitness scores and scores on mathematics compared to scores on English (Chomitz et al., 2008). Others found an association between cardiovascular fitness

and mathematics, but no association with reading (Telford et al., 2012). From these results, combined with our results, it seems that the association between cardiovascular fitness and mathematics is consistent in school-aged children. Although it should be acknowledged that genetic factors may have played a role and that it is easier to increase physical activity than to change physical fitness, a possible way to improve the mathematical performance in both SDC as non-SDC might be improving their cardiovascular fitness. This causality for mathematics is supported by a quasi-experimental study which reported a positive benefit of physical education on especially mathematical performance (Shephard et al., 1984). It is also supported by a randomized controlled intervention study which reported a significant improvement in mathematics, but not reading, after a cardiovascular exercise program (Davis et al., 2011).

Strengths of this study include the statistical control for the effects on school and class level. The effect of the school and class culture might play a dominant role in the relation between physical fitness and academic performance (Telford et al., 2012). The advantage of multilevel analyses is that it takes into account the nested variability of children within each school (Snijders & Bosker, 2011). A limitation of this study is the cross-sectional design, which makes it unable to confirm any type of causality. It is therefore not possible to confirm that increasing physical fitness causes increased performance on mathematics. Second, although a binary classification of socioeconomic status is commonly used in literature (Chomitz et al., 2008), it may partly account for the limited effects found between SDC and non-SDC in this study. The advantage of using the current classification is that it can be obtained from the personal school files of the children.

In conclusion, this study shows that SDC have a comparable physical fitness but are still behind in academic performance, compared with non-SDC attending to the same school. A positive association between cardiovascular fitness and spelling performance was found in non-SDC and between cardiovascular fitness and mathematics for non-SDC, as well as SDC. This finding is relevant in understanding the academic performance of preadolescent children given the worldwide pressure on and importance of improving academic performance (Chomitz et al., 2008).

REFERENCES

- Adam, C., et al. (1988). *EUROFIT: European test of physical fitness*. Rome: Council of Europe, Committee for the Development of Sport.
- Adler, N. E., & Ostrove, J. M. (2006). Socioeconomic status and health: What we know and what we don't. *Annals of the New York Academy of Sciences*, 896(1), 3-15.
- Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review*, 30(4), 331-351.
- Brus, B. T., & Voeten, M. (1973). *Een minuut test: Verantwoording en handleiding (One minute test: Manual)*. Nijmegen: Berkhout.
- Castelli, D. M., Hillman, C. H., Buck, S. M., & Erwin, H. E. (2007). Physical fitness and academic achievement in third- and fifth-grade students. *Journal of Sport and Exercise Psychology*, 29(2), 239-252.
- Chomitz, V. R., Slining, M. M., McGowan, R. J., Mitchell, S. E., Dawson, G. F., & Hacker, K. A. (2008). Is there a relationship between physical fitness and academic achievement? positive results from public school children in the Northeastern United States. *Journal of School Health*, 79(1), 30-37.
- Cole, T. J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: International survey. *BMJ*, 320(7244), 1-6.
- Danielzik, S., Czerwinski-Mast, M., Langnäse, K., Dilba, B., & Müller, M. (2004). Parental overweight, socioeconomic status and high birth weight are the major determinants of overweight and obesity in 5-7 y-old children: Baseline data of the Kiel Obesity Prevention Study (KOPS). *International Journal of Obesity*, 28(11), 1494-1502.
- Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., et al. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: A randomized, controlled trial. *Health Psychology*, 30(1), 91-98.
- De Wijs, A., Kamphuis, F., Kleintjes, F., Tomesen, M. (2010). *Spelling voor groep 3 tot en met 6: Wetenschappelijke verantwoording (Scientific justification for spelling examination in first-fourth grade)*. Arnhem: Cito.
- Dishman, R. K., Berthoud, H., Booth, F. W., Cotman, C. W., Edgerton, V. R., Fleshner, M. R., et al. (2006). Neurobiology of exercise. *Obesity*, 14(3), 345-356.
- Ebbeling, C. B., Pawlak, D. B., & Ludwig, D. S. (2002). Childhood obesity: Public-health crisis, common sense cure. *The Lancet*, 360(9331), 473-482.
- Eveland-Sayers, B. M., Farley, R. S., Fuller, D. K., Morgan, D. W., & Caputo, J. L. (2009). Physical fitness and academic achievement in elementary school children. *Journal of Physical Activity & Health*, 6(1), 99-104.
- Field, A. (2005). *Discovering statistics using SPSS for windows: Advanced techniques for beginners (Introducing statistical methods series)*. London: Sage Publications Limited.
- Grice, J. W., & Harris, R. J. (1998). A comparison of regression and loading weights for the computation of factor scores. *Multivariate Behavioral Research*, 33(2), 221-247.
- Janssen, J., Verhelst, N., Engelen, R., Scheltens, F. (2010). *Wetenschappelijke verantwoording van de toesten Rekenen-Wiskunde voor groep 3 tot en met 8 (Scientific justification for mathematics examination in first-fifth grade)*. Arnhem: Cito.
- Kwak, L., Kremers, S. P. J., Bergman, P., Ruiz, J. R., Rizzo, N. S., & Sjöström, M. (2009). Associations between physical activity, fitness, and academic achievement. *The Journal of Pediatrics*, 155(6), 914-918.
- Malina, R. M. (2001). Physical activity and fitness: Pathways from childhood to adulthood. *American Journal of Human Biology*, 13(2), 162-172.

- Ministry of Education, Culture and Science. (2006). *Brochure nieuwe gewichtenregeling basisonderwijs (Brochure new weighting system elementary school)*. Zoetermeer: CFI.
- North, T. C., McCullagh, P., & Tran, Z. V. (1990). Effect of exercise on depression. *Exercise and Sport Sciences Reviews, 18*(1), 379-415.
- O'Dea, J. A., & Mugridge, A. C. (2012). Nutritional quality of breakfast and physical activity independently predict the literacy and numeracy scores of children after adjusting for socioeconomic status. *Health Education Research, 27*(6), 975-985.
- Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjörström, M. (2008). Physical fitness in childhood and adolescence: A powerful marker of health. *International Journal of Obesity, 32*(1), 1-11.
- Riddoch, C. (1990). *Northern Ireland fitness survey-1989: The fitness, physical activity, attitudes and lifestyles of Northern Ireland post-primary schoolchildren*. Belfast: Division of Physical and Health Education, The Queen's University of Belfast.
- Rosnow, R. L., Rosenthal, R., & Rubin, D. B. (2000). Contrasts and correlations in effect-size estimation. *Psychological Science, 11*(6), 446-453.
- Ruiz, J. R., Rizzo, N. S., Hurtig-Wennlöf, A., Ortega, F. B., Wärnberg, J., & Sjörström, M. (2006). Relations of total physical activity and intensity to fitness and fatness in children: The European Youth Heart Study. *The American Journal of Clinical Nutrition, 84*(2), 299-303.
- Sauka, M., Priedite, I. S., Artjuhova, L., Larins, V., Selga, G., Dahlström, Ö, et al. (2011). Physical fitness in Northern European youth: Reference values from the Latvian physical health in youth study. *Scandinavian Journal of Public Health, 39*(1), 35-43.
- Shephard, R. J., et al. (1984). Required physical activity and academic grades: A controlled study. In J. Ilmarinen, & I. Valimaki (Eds.), *Children and sport* (pp. 58-63). Berlin: Springer-Verlag.
- Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: A meta-analysis. *Pediatric Exercise Science, 15*(3), 243-256.
- Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research, 75*(3), 417-453.
- Snijders, T., & Bosker, R. (2011). *Multilevel analysis: An introduction to basic and advanced multilevel modeling*. London: Sage Publications Limited.
- Tappe, K. A., Glanz, K., Sallis, J. F., Zhou, C., & Saelens, B. E. (2013). Children's physical activity and parents' perception of the neighborhood environment: Neighborhood impact on kids study. *International Journal of Behavioral Nutrition and Physical Activity, 10*(1), 39.
- Taras, H. (2005). Physical activity and student performance at school. *Journal of School Health, 75*(6), 214-218.
- Telford, R. D., Cunningham, R. B., Telford, R. M., & Abharatna, W. P. (2012). Schools with fitter children achieve better literacy and numeracy results: Evidence of a school cultural effect. *Pediatric Exercise Science, 24*(1), 45-57.
- Winter, B., Breitenstein, C., Mooren, F. C., Voelker, K., Fobker, M., Lechtermann, A., et al. (2007). High impact running improves learning. *Neurobiology of Learning and Memory, 87*(4), 597-609.
- Woodfield, L., Duncan, M., Al-Nakeeb, Y., Nevill, A. M., & Jenkins, C. (2002). Sex, ethnic and socio-economic differences in children's physical activity. *Pediatric Exercise Science, 14*, 277-285.

