Physically active academic lessons

de Greeff, Johannes Wilhelmus

Publication date:
2016

CHAPTER 6

Summary & general discussion

SUMMARY OF THE MAIN FINDINGS

In Chapter 1 we hypothesized that physical fitness is a mediator between socioeconomic status (SES) and cognition (executive functions and academic performance). Physical fitness can only be considered a mediator when all relations between SES, physical fitness and cognition are significantly related with each other. Therefore, we started the research of the current thesis by first investigating the relationships between physical fitness, executive functions and academic performance in both socially disadvantaged children (SDC) and children without this disadvantage (non-SDC). The second purpose and the main aim of the current research, was to investigate the effects of physically active academic lessons on physical fitness and executive functions.

Chapter 2 showed that SDC scored significantly lower on academic performance compared with non-SDC. Secondly, Chapter 2 showed that SDC and non-SDC did not differ on physical fitness and that within both SDC and non-SDC, cardiovascular fitness was positively related with mathematics. For spelling, the relationship with cardiovascular fitness was only found in non-SDC and not in SDC. In Chapter 3 the two main findings were that SDC scored lower than non-SDC on one of the domains of executive functions (cognitive flexibility) and that cardiovascular fitness was related with cognitive flexibility. The findings in Chapter 2 and 3 therefore indicate that SDC scored lower than non-SDC on cognitive flexibility and academic performance. SDC did not differ from non-SDC on physical fitness and therefore physical fitness is not a mediator between SES and cognition. Chapter 2 and 3 also indicate that physical fitness was related with multiple domains of cognition. From these findings we cannot confirm any type of causality, however, increasing cardiovascular fitness in both SDC as well as non-SDC might be beneficial for mathematics or cognitive tasks that require cognitive flexibility.

During this thesis, a 2-year classroom-based intervention program was developed that focuses on integrating physical activity into the routine academic lessons such as mathematics, spelling and reading (‘Fit en Vaardig op school’). In Chapter 4 and 5 the effects of these physically active academic lessons on BMI, physical fitness and executive functions are investigated. The two main findings from Chapter 4 are that after one intervention year, the lessons had no effects on cardiovascular or muscular fitness and a positive effect on BMI in third grade children. In this subgroup, BMI of the intervention group did not change, whereas BMI in the control group increased significantly. The main findings from Chapter 5 were that after two intervention years, the lessons had a positive effect on speed-coordination and a negative effect on static strength. The lessons had no effect on executive functions.

Relationships between physical fitness, executive functions and academic performance in SDC and non-SDC

The current thesis shows that cardiovascular fitness was related with a specific domain of executive functions (cognitive flexibility) and with multiple domains of academic performance (mathematics and spelling). These findings complement the results of previous studies which shows that improvements in cardiovascular fitness co-occur with improvements in the brain structural network responsible for learning, such as increased white matter in the hippocampus (Chaddock, Erickson, Prakash, Kim et al., 2010) and the basal ganglia (Chaddock, Erickson, Prakash, VanPatter, et al., 2010). These findings also provide some support for the cardiovascular fitness hypothesis (Etnier et al., 2006), which states that by being physically active regularly, cardiovascular fitness will improve which results in improvements in cognition. It is hypothesized that by being physically active regularly, cerebral blood flow increases and, in the long term, structural changes of the brain structural network occur which will result in cognitive improvements (Etnier et al., 2006). However, these cross-sectional relationships did not provide insight into the causality and further research is needed to support this hypothesis. It did however provide a good argument for starting a randomized controlled trial which investigates the effects of physical activity on cognition.

One of the additional questions in Chapter 2 and 3 was whether or not differences could be found between SDC and non-SDC in physical fitness, executive functions and academic performance. Previous literature has shown that SDC are at risk for low physical fitness levels (Duncan et al., 1994; Poulton et al., 2002) and score low on executive functions (Ardila et al., 2005; Waber et al., 2006) and academic performance (Chomitz et al., 2008; Sirin, 2005). It was therefore hypothesized that SDC scored lower on physical fitness, executive functions and academic performance compared with non-SDC. Assuming that physical fitness is related with cognition, it was also hypothesized that a low physical fitness in SDC might partly explain their lower scores on executive functions and their low academic performance. The results in Chapter 2 confirmed that SDC scored lower on all domains of academic performance (mathematics, spelling and reading) and the results in Chapter 3 confirmed that SDC scored lower on one of the domains of executive functions (cognitive flexibility). However, SDC did not score lower on physical fitness. These results indicate that the lower academic performance cannot be partly explained by physical fitness and physical fitness is therefore not a mediator between SES and cognition.

Effects of physically active academic lessons on physical fitness and executive functions

A 2-year classroom-based intervention program was developed that focuses on integrating physical activity into the routine academic lessons such as mathematics, spelling and reading (‘Fit en Vaardig op school’). The children in the intervention group participated in three physically active academic lessons per week with a duration of 20-30 minutes per lesson. After two intervention years (22 weeks per year), only small or no significant effects were found on physical fitness and executive functions. In addition, Chapter 4 showed that there we no differential responses by initial level of physical fitness. This indicates that there were also no effects on physical fitness or executive functions for the children with initial lower levels of physical fitness. Based on previous studies, larger effects on physical fitness and executive functions were expected. For example, a 9-month after-school physical activity program (FIT Kids program), including at least 60 min of MVPA per day, resulted in improvements in working memory (Hillman et al., 2011; Kamijo et al., 2011), inhibition and cognitive flexibility (Hillman et al., 2011). Furthermore, the FIT Kids program also resulted in improved cardiovascular fitness (Kamijo et al., 2011). As was explained in Chapter 1, it was assumed that regular MVPA increases physical fitness which in turn leads to cognitive improvements. The fact that the physically active academic lessons did not result in improvements in physical fitness might explain the lack of significant improvements in executive functions.

It is known that increasing physical fitness in preadolescent children can be challenging, because it is determined for a large part by other factors such as genetic factors. It is possible that the children already scored relatively high on physical fitness, making it difficult to improve it even further. However, in Chapter 2 the performance on physical fitness was compared with a relative large sample of 8-year-old Latvian children (Sauka et al., 2011), which showed that both SDC and non-SDC in the current research had lower cardiovascular and muscular fitness scores. In addition, Chapter 4 has shown that for children with initially lower levels of physical fitness or children with initially higher BMI no effects were found on physical fitness. An alternative explanation can be found when looking at the (internal) exercise load of the lessons which was objectively measured during the first intervention year with heart rate monitors. Although the differences in mean heart rate between children was large, heart rate monitoring results showed an average estimated MVPA engagement of 60%, which can be translated in 14 minutes of MVPA per lesson (Mullender-Wijnsma et al., 2015). It can be argued that an intervention program that provides an average of 14 minutes of extra in-school MVPA, three times a week, is not enough to improve physical fitness in this age range.

Conclusions and future recommendations

Research on integrating physical activity into academic lessons is in its infancy and the true potential has yet to be fully understood, but it has undoubtedly important potential value in the school curriculum. This research has shown that it is possible to implement physical activity into the classroom without the cost of academic instruction time. The current lessons provide primary school teachers a novel strategy to integrate physical activity into the regular academic lessons. By integrating physical activity into the academic content children were challenged and motivated throughout the schoolyear. After one intervention year, the lessons had a positive effect on BMI in third grade children. The lessons had small or no effects on physical fitness and no effect on executive functions. Despite these limited findings, the major strengths of the 'Fit en Vaardig op school'-project was that it used a cluster randomized controlled study design, a large sample size and a relative long intervention period, making it possible to draw strong conclusions from the data.

The findings in the current thesis have also provided us some important suggestions for future directions. First, one of the challenges in this line of research is the difficulty in measuring executive functions in typically developing children. Although the tests are reliable and valid for preadolescent children (for details see method section in Chapter 3), the tests are originally developed for detecting deficiencies in a normal child's brain (Pennington & Ozonoff, 1996). It is unknown how suitable the tests are in measuring changes over time in preadolescent children without deficiencies. Chapter 5 showed that grade was a significant predictor for the scores on all of the tests for executive functions, indicating that third grade children scored significantly higher on all tests compared with second grade children. It is therefore likely that the tests are sensitive enough to detect developments in executive functions after one schoolyear. It is possible that a smaller but still relevant increase in performance cannot be detected by the tests used in the current thesis.

Second, the finding that physically active academic lessons did not improve physical fitness highlight the difficulty to positively influence physical fitness in primary school children. Recently, an increasing number of studies are beginning to question whether it is crucial to increase physical fitness in order to achieve cognitive benefits (Koutsandreou, 2016; Pesce, 2013). It is possible that the cognitive demands of physical activity moderate the effect of physical activity on cognitive functions. This indicates that physical activity programs with a high cognitive engagement (e.g. motor coordination or complex coordinative exercises), rather than low cognitive engagement (e.g. repetitive and nonadaptive exercises) might enhance cognitive performance. Future research should therefore not only focus on the quantitative characteristics of physical activity (i.e. dose-response relations between physical activity and cognitive performance), but also on the qualitative characteristics of physical activity (i.e. type of physical activity) (Pesce, 2012). To further understand the effects of physical activity on cognition in primary school children, we will therefore examine the effects of two intervention programs with different cognitive demands (aerobic exercise versus coordinative exercise) on cognitive performance.

REFERENCES

Ardila, A., Rosselli, M., Matute, E., & Guajardo, S. (2005). The influence of the parents' educational level on the development of executive functions. *Developmental Neuropsychology, 28*(1), 539-560.

Chaddock, L., Erickson, K. I., Prakash, R. S., Kim, J. S., Voss, M. W., VanPatter, M., et al. (2010). A neuroimaging investigation of the association between aerobic fitness, hippocampal volume, and memory performance in preadolescent children. *Brain Research, 1358*, 172-183.

Chaddock, L., Erickson, K. I., Prakash, R. S., VanPatter, M., Voss, M. W., Pontifex, M. B., et al. (2010). Basal ganglia volume is associated with aerobic fitness in preadolescent children. *Developmental Neuroscience, 32*(3), 249-256.

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.

Duncan, G. J., Brooks-Gunn, J., & Klebanov, P. K. (1994). Economic deprivation and early childhood development. *Child Development, 65*(2), 296-318.

Etnier, J. L., Nowell, P. M., Landers, D. M., & Sibley, B. A. (2006). A meta-regression to examine the relationship between aerobic fitness and cognitive performance. *Brain Research Reviews, 52*(1), 119-130.

Hillman, C. H., Kamijo, K., & Scudder, M. (2011). A review of chronic and acute physical activity participation on neuroelectric measures of brain health and cognition during childhood. *Preventive Medicine, 52*, S21-S28.

Kamijo, K., Pontifex, M. B., O'Leary, K. C., Scudder, M. R., Wu, C., Castelli, D. M., et al. (2011). The effects of an afterschool physical activity program on working memory in preadolescent children. *Developmental Science, 14*(5), 1046-1058.

Mullender-Wijnsma, M. J., Hartman, E., de Greeff, J. W., Bosker, R. J., Doolaard, S., & Visscher, C. (2015). Moderate-to-vigorous physically active academic lessons and academic engagement in children with and without a social disadvantage: A within subject experimental design. *BMC Public Health, 15*(1), 404.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 37*(1), 51-87.

Pesce, C. (2012). Shifting the focus from quantitative to qualitative exercise characteristics in exercise and cognition research. *Journal of Sport and Exercise Psychology, 34*(6), 766-786.

Poulton, R., Caspi, A., Milne, B. J., Thomson, W. M., Taylor, A., Sears, M. R., et al. (2002). Association between children's experience of socioeconomic disadvantage and adult health: A life-course study. *The Lancet, 360*(9346), 1640-1645.

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.

Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research, 75*(3), 417-453.

Slingerland, M., Oomen, J., & Borghouts, L. (2011). Physical activity levels during Dutch primary and secondary school physical education. *European Journal of Sport Science, 11*(4), 249-257.

Waber, D. P., Gerber, E. B., Turcios, V. Y., Wagner, E. R., & Forbes, P. W. (2006). Executive functions and performance on high-stakes testing in children from urban schools. *Developmental Neuropsychology, 29*(3), 459-477.